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The Fluctuation of Attention.

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THE FLUCTUATION OF ATTENTION.[1]

PART I. INTRODUCTORY.

Attention is generally conceded to be the *terra incognita* of psychology. It is, however, a subject which has come prominently to the front of late, and has become a topic of some experimentation. So far, however, little more has been done than to present the problem, and to show some of the difficulties in the way of its solution.[2] The present study, however, was not begun so much with the hope of solving the difficulties which attend the understanding of attention, as with the hope of giving some light upon a practical problem of ethics, which, no doubt, in some form or other, confronts every intelligent human being.

There are probably few who have not observed in themselves or others an occasional change of feeling for another person, a certain occupation or amusement. It may have been but a passing wave of dislike, or a short period of irresponsiveness; while it may have been an intense feeling of revulsion. Usually this comes for no adequate reason, or no reason at all, and disappears as unceremoniously as it came, often leaving in its wake a heightened feeling of appreciation, its polar opposite. This aversion may last but a few seconds or hours, or it may continue for months or even years, and then perhaps wear away so gradually that its disappearance is made unconscious. Per-

[1] The laboratory work here described was done at Clark University. I wish to thank the members of the laboratory for their hearty coöperation, and to express my indebtedness to Dr. Hall for his suggestions and encouragement, and to Dr. Sanford for his constant assistance and supervision.

[2] For recent experimental work on attention see 'Die Aufmerksamkeit und die Funktion der Sinnesorgane,' by W. Heinrich, *Zeitsch. für Psychol.*, Vol. IX., Nos. 5 and 6, pp. 343-388.

'Attention: Experimental and Critical,' by Frank Drew, *Am. Journal of Psychol.*, July, 1896.

'Attention and Distraction,' by Alice J. Hamlin, *Am. Journal of Psychol.*, October, 1896.

haps the ways in which this inconsistency appears to us the most strikingly are in the fluctuations of religious feeling as shown by occasional 'backslidings;' the periodic inability to deny some strong appetite, as it often is with the inebriate who is trying to reform; and the changes of attitude in the individual's social relations, as evidenced by the great number of divorces and the complications of social etiquette. If, however, we look more closely, we find that a marked similarity exists between these more striking forms of changeability and other mental phenomena. The enjoyment of variety in the styles of dress and architecture, music, the revulsion at being bored, the monotony of routine, might be taken with a host of other common experiences to illustrate this same principle; but enough has already been said to make clear the central idea here implied, that the power to work along the line of a certain mental activity tends to be intermittent rather than continuous.

or change of attention

The primary problem presented by this condition of things is, How far are we responsible for this inconstancy and the conduct which naturally follows from it?

By looking closely into these instances of change in the mental attitude we see that we have to deal with conditions of attention. The prevalence in the mind of an idea is of itself enough to control conduct. In speaking of the effect of an idea upon action, Professor James says: "Let it once so dominate, let no other ideas succeed in displacing it, and whatever motor effects belong to it by nature will inevitably occur—its impulsion, in short, will be given to boot, and will manifest itself as a matter of course. This is what we have seen in instinct, in emotion, in common ideo-motor action, in hypnotic suggestion, in morbid impulsion, and in *voluntas invita*, the impelling idea is simply the one which possesses the attention."[1] We may ask, Is it simply moral perversity which prevents the child from studying his lessons constantly, or are there natural and sufficient reasons which make it impossible for him to do so? Does it show insincerity when the clergyman leaves his parish and seeks recreation where demands of a religious nature will not be made upon him? And, finally, does a violent or passionate act

[1] James's Psychology, Vol. II., p. 559.

necessarily portray a villain, or may it simply indicate the exaggerated intensity of a normal functioning? These questions are all evidently included in the problem which it is the main object of this research to help solve, namely, What determines the time at which and time during which a given idea or set of ideas shall have a predominating influence upon the mind; and what determines the intensity of that domination? In short, what determines the direction and intensity of attention?

Even with our subject thus limited, it is evident that an exhaustive treatment, such as would follow it into all of its ramifications, would require nothing less than a working over of the whole field of psychology. Artificial limits will therefore have to be placed, and omissions made necessary which may seem to deprive this treatment of its due symmetry and completeness.

While it may not be found that the following of any rigid classification of work will be of advantage in the present paper, we can perhaps best locate ourselves in this field of inquiry by dividing the work in a more or less formal way.

It is evident that there are two grand divisions to our subject as a whole:

First, the study of the conditions favorable to a change in the direction of attention.

Second, the study of the conditions favorable to the retention of one direction of attention.

These conditions may be divided into those that are (1) subjective, or those referring to the particular state of the person's mind; and those that are (2) objective, having to do with objective conditions and the nature of the object of attention.

We, therefore, have:

1. The subjective conditions for the change in the direction of attention.

2. The subjective conditions for the retention of the direction of attention.

3. The objective conditions for the change in the direction of attention.

4. The objective conditions for the retention of the direction of attention.

In the present paper I shall be able to deal at length with only the first two of these divisions.

We need not look far to find a close analogy to these phenomena of intermittence in the fatigue and rest which we all undergo each day. At night the limbs feel heavy, a general uncomfortable feeling pervades the body, and the mind acts slowly and with frequent distractions. A good night's rest, however, seldom fails to relieve these symptoms of fatigue and brings with it the buoyancy and vigor always associated with morning hours.

Another fact that indicates mental distraction to be a result of mental exhaustion is that young children are incapable alike of continued mental or physical application, showing inattention after an attempt at the one, and the familiar signs of bodily fatigue after the other. Dr. Hürliman states that a child of four cannot keep a uniform upright position for more than five minutes.[1] Continued mental effort is found to be correspondingly difficult. In connection with certain researches of Dr. G. Stanley Hall, I have watched children in the kindergarten when set at making short, vertical lines (soldiers) between parallel horizontal lines, upon paper. Children between four and five years showed evident signs of fatigue within ten minutes of the time of starting. When the experiment was conducted longer these signs became more pronounced. The work would be momentarily dropped to look at one's neighbor's work, or at some object at hand that was more entertaining. When urged to continue his work, the child would make a few lines and then relax again into his general observations. Signs of physical fatigue were also marked. The posture would be frequently changed, the pencil changed from one hand to the other, the head laid upon the arm, and the feet frequently shuffled.

Since inattention and muscular fatigue are conditions that seem so nearly parallel, let us examine more closely the principles that control the latter. It is well known that the continued working of a muscle will result in the inability to work through fatigue. A heavy weight can be held at arm's length but a moment. The heart rests after each contraction; and the process of respiration consists of a series of muscular contractions and relaxations. This fatigue is perhaps best studied

[1] *Zeitschrift für Schulgesundheitsflege*, No. 6, 1892, p. 266.

by means of the ergograph, the instrument used by W. P. Lombard and Professor Mosso. By means of this instrument a single muscle can be worked until exhausted, and the amount of work done in doing this accurately estimated. By placing the right palm flat upon the table and moving the index finger to the left, the muscle is used which was employed in the following demonstration. A cord, attached to the outer end of a thimble fitting tightly on the end of the index finger, runs to the right, passes over a pulley, and is attached to any weight desired. A pen moving horizontally and attached between the finger and the pulley marks upon the revolving drum of a kymograph, thus registering the amount of each contraction or the height to which the weight is lifted. The following cuts on page 6 are from records taken from myself.[1]

From *a* to *b*, Fig. 1, are shown the contractions of the muscle above indicated under a weight of 846 gr. The contractions were made once a second. It is seen that the degree of the contractions grows less until *b* is reached, when the power of moving the weight was lost.

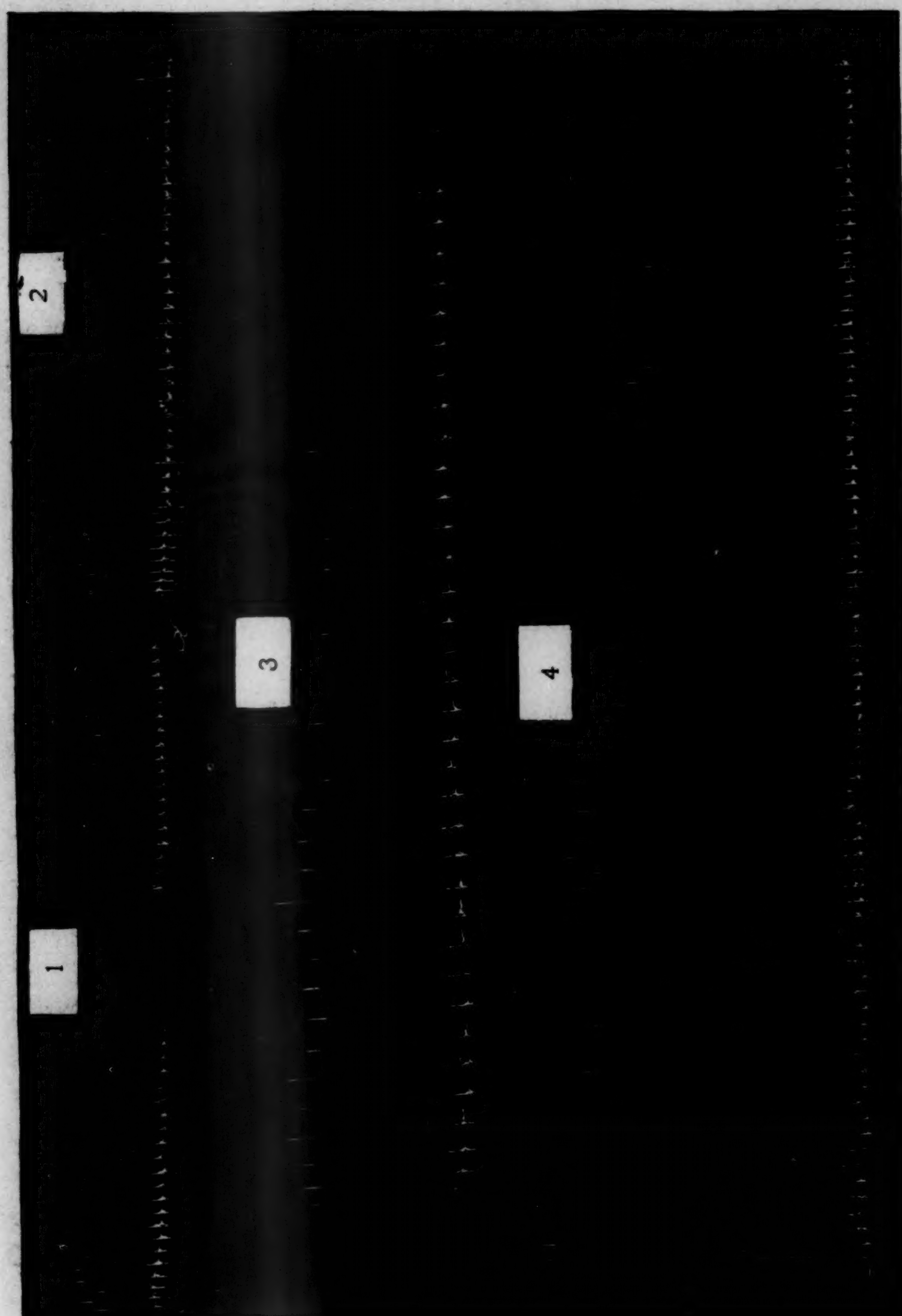
Fig. 2 shows a similar record when the weight had been reduced to 706 gr. It is seen that the contractions were more ample and continued longer, thus making the amount of work done approximately the same.

Fig. 3 is a record taken when the weight was 846 gr. (the same as in Fig. 1), but the contractions came once in two seconds instead of once a second. Here we have 35 distinct contractions as against 21 in Fig. 1, and, besides, the amplitude of the contraction is considerably greater. Many other records might be given to illustrate this principle: that the harder the work, the quicker is the exhaustion.

The phase brought in by Fig. 3 is evidently explained by the constant process of recuperation which seems to take place. This is also illustrated by the portion *c d* of Fig. 1. After the muscle had became so exhausted that it became impossible to raise the weight, a rest of eight seconds represented by the line *b c* was allowed in which no effort was made. Then the con-

[1] See Angelo Mosso, 'Les lois de la fatigue étudiées dans des muscles de l'homme.' *Travaux de Lab. de Physiol. de Turin*, 1889, pp. 149–212.

tractions shown by *c d* were made. This shows that the process of recuperation must have gone on rapidly during the rest.



FIGS. 1, 2, 3, AND 4.

Fig. 4 shows this in a no less striking manner. Here the contractions were made once a second, while the weight was but 445 gr. The contractions are at first markedly ample and

lessen only slightly when the end is reached. The actual experiment was continued for 166 contractions more without any distinct decrease in the amplitude. This shows that the rate of working represented by the 'curve,' after this slight decrease at the beginning, was balanced by the rate of recuperation.

Exact mathematical measurements might easily be made showing the equivalent of this work in dynes, and the value of the energy generated. So many varying physical and mental factors influence this, however, that it would be difficult to estimate them for the purpose of foretelling kinetic results. Yet enough has been ~~given to make it plain~~ that the rate of muscular fatigue indicates the ratio between the rate with which energy is supplied to the muscle and the rate with which it is drafted off.

The following axioms are directly or indirectly an evident result of these data:

1. The more intense the activity, the quicker is the fatigue.

2. The longer the activity the greater is the degree of fatigue, if the demand for energy is greater than the supply.

3. The greater the degree of exhaustion, the slower must the rate of working become.

4. The more complete the rest, the more rapid is the recuperation.

5. The longer the rest the greater the recuperation.

6. The greater the degree of recuperation, the greater is the rapidity of work made possible.

Now Professor Lombard[1] seems to show that this fatigue is due almost entirely to the exhaustion of the nerve cells which innervate the muscle, from the fact that when the power of voluntary contraction is lost by fatigue, contractions may be produced by an electric current administered to the nerve. What we have ~~been studying, therefore,~~ is evidently the laws of neural fatigue.

Before proceeding to the more purely mental aspect of our problem, I wish to note briefly the results of a previous research made with Professor Münsterberg at the Harvard Laboratory, the account of which has been in part published.[2] From this

[1] *Am. Journal of Psychology*, Vol. III., p. 24.

[2] Report from the Harvard Psychological Laboratory, *Psychological Review*, January, 1896.

work it was made evident that what has been called the fluctuation of attention, as when a slight visual impression alternately comes and goes, is not due to a change in the direction of attention but to a fatiguing of the sense organ, or at least to a change in the nervous mechanism less central than the seat of consciousness. One of the strongest reasons for this is that when the ocular impression is no longer noticeable, the object can be visualized mentally, thus showing that the attention still retains its previous direction. In fact if the attention had changed its direction when the visual object became invisible, the moment of its disappearance would have been unknown, and the idea of the object would not have returned until the object reappeared, no distinction between the visual image and the sensation being possible. The same was found to be true of sensations of touch and of temperature. It seems safe to say, therefore, that the sense organs act independently of the attention.

By taking the time of consecutive disappearances and appearances in long series of these sensations, and varying the intensities of the stimuli, it was found that for ocular sensations the larger and the lighter the object (on a black background) the greater became the time it was seen as compared with the time it was not seen.

For sensations of temperature it was also found that the more intense the sensation the longer was the sensation felt in comparison with the time it was not felt. For auditory sensations the same seemed true, though conditions prevented a satisfactory trial.

With sensations of touch the reverse was true, though this may be accounted for by the fact that, as touch came to be more and more distinct pressure, it prevented, to an increasing extent, the circulation necessary for sustaining the sense organ.

Here, then, it will be observed, is a set of data exactly opposed, as it would appear, to the axioms just drawn up for neural activity in the case of muscular action.

The fact that what has been commonly called the fluctuation of attention is not a central phenomenon, does not, however, prevent its real existence at the centre of consciousness. Although the mental image of a visual object may survive the

ocular image by a considerable time, usually completely bridging over the absence of the latter, the mental image itself is subject to alternate disappearances and appearances. Recent work of Dr. E. H. Lindley, to be referred to later, gives valuable data upon this point. Let any one visualize (with eyes closed if more convenient) a simple object like a red disc the size of a penny. At first it is very distinct. The color is clear and natural, and slight blemishes and irregularities, usually found in such a surface, are not left out. After a moment the color fades, and the disc disappears, in spite of the effort to retain it. It shortly reappears, however, with a distinctness comparable to that of its first appearance. This experiment can be continued indefinitely.

A similar experience is had when one tries to recall a word or name once forgotten. All irrelevant ideas are inhibited, and the attention held as if by some vague notion of its whereabouts over a blank or cavity which corresponds in some general way to the features of the word desired. Suddenly, if the effort is successful, it pops up as if by its own accord. Often this process is assisted by some cue which acts through some path of association. But even then there would seem to be some principle of spontaneity acting in the ideational centres which is not fully under the control of volition.

PART II. EXPERIMENTAL.

Experiment A.

Since it is evident that the inability to continue in one line of mental work may result from fatigue, I wished to arrange some kind of mental work which would exercise but a narrow range of activity, and yet keep that activity at its highest degree of intensity. The object was to study the effect of fatigue upon the attention involved.

A tape one-half inch wide and eight feet long was prepared, having typewritten capitals on one side. The letters were separated by a space equal to that used between adjoining words; for one half of the tape no one letter was followed twice by the same letter; the other half was a repetition of this. The tape

was joined at the ends and made to revolve in belt fashion horizontally by being supported by a rimmed truck at one end, and the drum of a kymograph at the other, the latter being used as a motor. At one end of the tape was placed a screen with an opening just large enough to allow the subject to see one letter at a time as it passed. The experimenter, placed at the other end, could read the letters from the other half of the tape in the same order as the subject, but without being confined to a small screen-opening.

The tape was set revolving at the fastest rate at which the subject could read the letters aloud. Whenever a mistake or omission occurred, the experimenter recorded the same with an electric key upon a smoked drum. The subject was also provided with a key which recorded his conscious errors, and was practiced in its use, to make the recording as automatic as possible. It was soon found that the subject's mistakes were conscious with hardly an exception, and that his record of errors was, if anything, more correct than the experimenter's.

Each experiment was conducted during a time of from ten to forty minutes, so that fatigue was likely to be involved to a considerable extent. The rate varied for different subjects, and at different times for the same subject, from the passing of two to the passing of four letters by the opening of the screen in a second; but the rate during one experiment remained constant.

The kymograph records of these experiments show: First, that the errors increase towards the end of the experiments; especially in the longer ones; and, second, a marked tendency for the errors to come in periodic groups. A group of errors unquestionably means that the faculties exercised by the subject are acting less energetically and are, therefore, having a period of comparative rest; and this rest is shown by the renewed activity which followed each group of errors.

These results are obviously in accordance with the laws of muscular fatigue as indicated above, where it was seen that an expense of energy greater than the supply was followed by the inability to work, and that this in turn was followed by a period of activity.[1]

[1] See Lombard, loc. cit.

Let us now turn to the subjective experiences accompanying this.

When the experiment was continued long enough to make the errors much more frequent toward the end, a feeling of fatigue became prominent. At such times several letters would be missed at once instead of one at a time, as it more frequently was before distinct fatigue set in. The subject would know perfectly well that several letters had escaped him, but the power to bring the mind back sharply to its work was wanting.

The question may be asked as to how far this fatigue was involved in the vocal muscles and eye adjustments. But one subject (Sh.) felt much fatigue in the muscles of the throat. This was not extreme enough, however, to interfere materially with speech. No fatigue was felt in the eye muscles.

There was often a tendency to get behind in the perception and pronunciation of the letters. Sometimes each of several letters would get by a little farther before pronounced until one would have to be skipped in order to catch up. This in itself would produce a comparatively regular periodicity in the errors even if there were no periodic fatiguing. The kymograph records show, however, that the errors did not often come regularly enough to be accounted for in this way, and that when the errors did come with great regularity they were so far apart as to be separated by eighty to a hundred letters. A gradual retardation, for so long a time as this, however, was not experienced by the subjects. The subjects' accounts of this show also that the tendency to get behind was much more frequent than the actual omission, and that a special effort made on that account often resulted in catching up again.

This brings us to perhaps the most interesting phase of the experiment, the distracting effect of extraneous ideas. There was no rate of speed that could be given the tape that would allow the subject to keep up and yet be an effective bar for any length of time against all foreign ideas. Yet it was found that, so long as the subject could keep up, the faster the rate the greater was the distraction of other ideas; and that ideas entirely disconnected from the work were more distracting than those immediately connected with it. Thus, the idea of getting

behind, although different from that involved in the work itself, often resulted in catching up, while the knowing of one's crossing the floor caused an omission.

The occasional flitting in of other ideas, though perhaps better called vague feelings than ideas, when the subject was straining every nerve to keep up, and yet, in some cases, without any apparent disturbance, suggests the interesting question as to where the attention was at the instant that this idea took its prominence in the mind. The sense organs were adjusted to the letters on the tape, and the muscles were working to favor that adjustment and to express the appropriate motor response. According to Ribot, therefore, the attention was on the tape. Professor James might consider it to be on the transient idea—we will say the idea of going too slow—although he would seem obliged to abandon the *sense organ adjustment* part of his theory. True, it might be said that the sense organ adjustment would be the same for the supposed idea and for the tape. But if sense organ adjustment may be the same for several different ideas, then it is evident that this ceases to be a part of attention which articulates itself characteristically for each idea, but only a rough and general attitude accompanying general classes of attentive states.

I can hardly see how the *muscle-sensation* part of Wundt's theory comes in in this case, though the presence of the feeling which precedes the ideational change and the growing clearness of the idea would seem to commit him in favor of the intruding ideas. And, since the subject might be supposed to have an *interest* in pronouncing all the letters which passed, we could doubtless place Stumpf with Wundt.

The distracting effect of many ideas suggested the application of some painful stimulation to the subject, while reading the letters at his fastest rate. Accordingly, a constantly increasing alternating current of electricity was passed through the hand of two of the four subjects in this experiment, Sh. and myself. When the current had reached to but a slight intensity no effect was noticed, except, perhaps, a slight distraction. But when a distinctly painful intensity had been reached, it seemed to serve as a prop to the attention and caused the mind to act with more

than usual clearness and alacrity. When, however, a much stronger intensity had been reached, the attention was diverted largely to it, causing long omissions in the reading. It was found that the reading of a story to Hh. had the same effect as the moderately painful current had upon Sh. and myself, and that the subject was afterwards able to give a good account of what had been read. A careful record taken from this subject with and without the reading showed that there were actually fewer mistakes with the reading. The opposite, however, was true with Sh. and myself. With all the subjects there was a strong tendency for the naming of the letters gradually to become automatic.

Experiment B.

In the last experiment the amount of work to be done remained constant, while the periods of relaxation were recorded by means of the errors. In Experiment B, I wished to measure the degree of relaxation primarily by means of the changed rate of working.

To do this I arranged columns of figures for adding, upon three large sheets of paper, eight and one-half by eleven inches. There were fifteen columns on each sheet, arranged in groups of three columns each, with twenty-seven numbers in each column, each number composed of one digit, zero being omitted. Each digit from 1 to 9 was used approximately the same number of times, though not so strictly as to exclude a certain amount of variety in the sums of the columns. A variety in the order of the figures was also introduced. These sheets were distinctly printed by means of the mimeograph, so that each subject could have his own set. The columns were distinguished for purposes of reference by the use of letters.

The experiment was conducted as follows: The sheets were arranged in order upon a table before the subject, the experimenter gave the signal for starting, and took the time required for adding each of the forty-five columns in turn, the subject constantly adding at the top of his speed. The signal for the finishing of each column was given by the subject's pronouncing aloud the sum at the head of each (the subject adding up-

ward), and the experimenter taking the time to fifths of seconds from a stop-watch, and also recording the sum given.

Each of the four subjects in this experiment added these fifteen groups of columns fifteen times, beginning the first time with the first group; the second time with the second group, and ending with the first; the third time beginning with the third group and ending with the second, and so on. The time required for the experiment varied with the subject and with the amount of practice. With one it took over three-quarters of an hour the first time, but with another less than twenty-five minutes.

Let us now turn to the method of working up the results.

The time taken for the addition of each of the columns was first arranged in forty-five columns, each column having fifteen time-measurements. Those in the first column of time-measurements showed the time for adding the first column of figures at each trial, in whatever part of the sheets the trial began. The second column of time-measurements showed the time required for adding the second column added at each trial, and so on. These columns of time-measurements were added separately and the average time-measurements found for each column. Each three of the columns was then averaged in turn, thus giving fifteen averages corresponding to the fifteen groups of columns added in the experiment. The effect in this result of beginning at different groups at the different trials is evidently to obviate the error resulting from one group being harder to add than another, thus keeping this objective condition constant. What these fifteen averages indicate is, therefore, the changes in the subjective conditions, due, we will suppose, to fatigue. This, however, is not strictly true, since the experiment was sometimes interfered with by more or less distant noises which frequently had the effect of exaggerating subjective tendencies. The solid curves[1] in Fig. 5 are plotted from these averages taken from the four subjects. There are a few points common to these curves which it may be well to note. There is at first a

[1] The figures at the left of the curves are a scale of the time in seconds, thus showing the rate of adding for each part of the sheets. The figures at the left of the dotted lines give a scale of mistakes.

rapid fatiguing shown by the increase of time which the second group took over the first. Next, a more or less marked acceleration, due, evidently, to a return of vigor, makes a new tack in

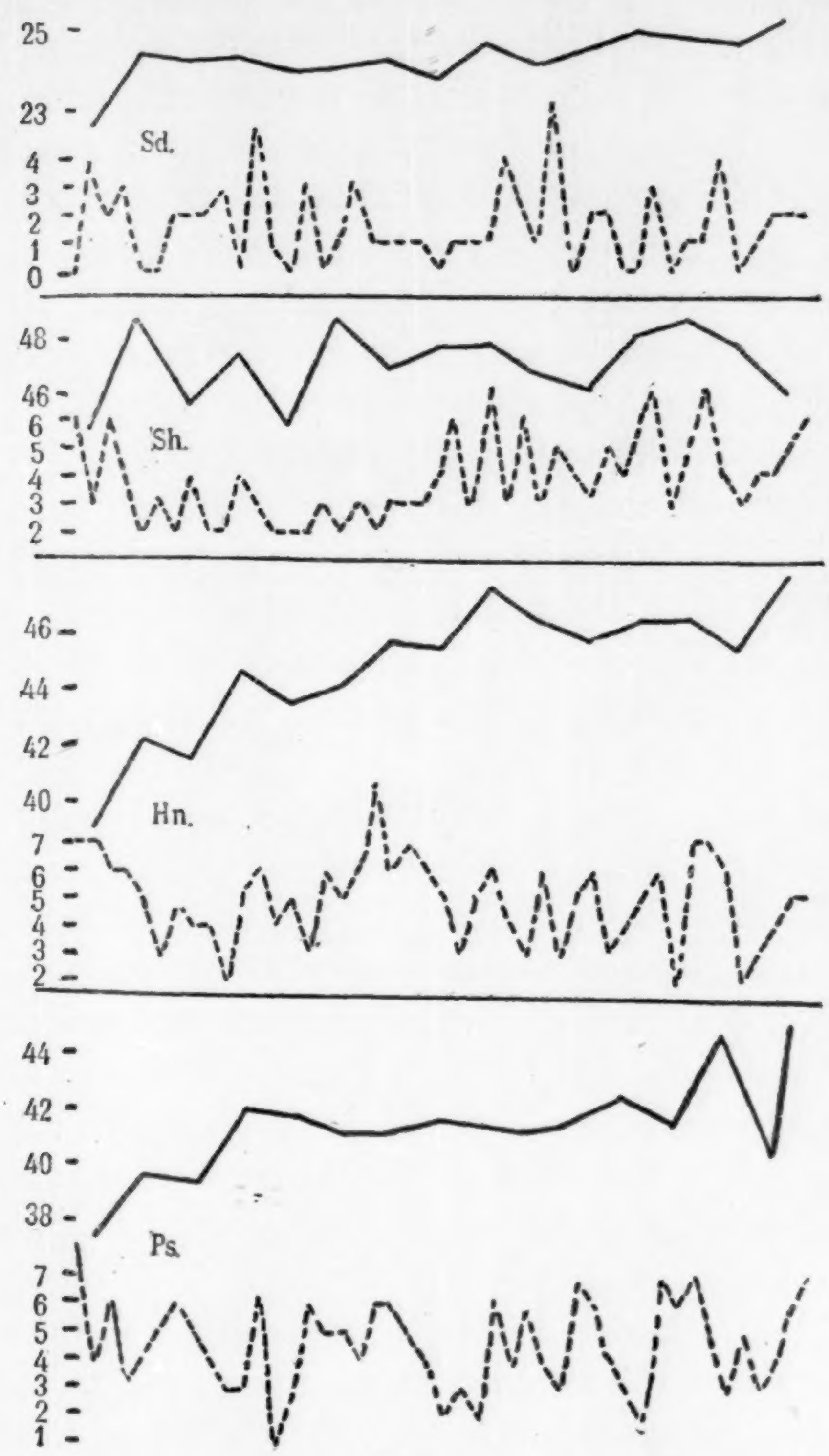


FIG. 5.

the curve. This is followed by a variety of ups and downs to the end, towards which, in all but one case, there has been a gradual slowing up. The subject's reason for the acceleration here was the anticipation of the end. The other subjects were not conscious of this.

These curves, however, do not give a correct impression of the variations in rate which actually occurred during one trial. This is because the process of averaging often offset a rapid addition in one place by a slow one in the corresponding place of another trial; and besides grouped too many columns together. To obviate this difficulty, a different system of tabulation was required. In this system the time taken to add a certain column on the sheets during the fifteen trials was kept in a column by itself, thus the column marked *A* on the tabulation sheet gave the time-measurements taken from adding the *A* column on the sheets of the experiment for the different trials. The record of each subject was kept separate as in the last case. Here the rotating method followed in the different trials served to distribute the general fatigue effect equally among the tabulation columns, thus making necessary another method than in the last system for the elimination of differences of difficulty in the addition columns. To do this, the tabulation columns were added and the average found for each column. A grand average was then taken of these averages. This final average was subtracted from each of the column averages, thus leaving for each column the difference, sometimes preceded by a plus and sometimes by a minus sign. When this difference was properly combined with any time-measurement of the column to which it belonged, it is evident that it effected a correction for the comparative ease or difficulty which the subject found in adding the corresponding column for that trial in the experiment sheets.

Thus, suppose the average for the tabulation column *A* to be 42.6 sec. and the grand average 41.3 sec. The difference, when 41.3 sec. is subtracted, is + 1.3 sec. This shows that the time for adding column *A* on the experiment sheets averaged 1.3 sec. more than the total average, or was by that much more difficult to add than the average. This amount then must be subtracted from each of the time-measurements in tabulation column *A* in order to apply the needed correction. Each measurement of the fifteen trials was corrected according to this method for all of the four subjects, and each trial was platted into a curve.

The following illustrative columns of figures show a com-

parison in seconds between the time-measurements before and after correction of the first and last trials of Ps.

As before stated, the sums were taken as pronounced by the subject in the experiment and the errors in addition thus kept account of. These were represented with the platted curves by placing a cross along a horizontal line above each curve at the point at which the mistake occurred. These mistakes were combined in the dotted curves, in Fig. 5, which show in what parts of the trials the mistakes were most frequent.

TABLE I.

First Trial.						Last Trial.					
Before Correction.	After Correction.	Before Correction.	After Correction.	Before Correction.	After Correction.	Before Correction.	After Correction.	Before Correction.	After Correction.	Before Correction.	After Correction.
39.0	34.4	57.8	49.5	59.0	60.2	35.0	30.4	46.0	37.7	40.4	41.6
51.0	50.7	44.2	39.8	49.6	51.0	31.4	31.1	40.4	36.0	45.4	46.8
39.4	45.3	49.0	52.4	45.0	47.9	31.2	37.1	34.6	38.0	35.4	38.3
61.4	61.1	31.0	55.3	62.0	59.7	32.8	33.1	43.0	47.3	40.8	38.5
50.4	48.0	49.0	52.9	53.0	52.7	31.2	28.8	28.4	32.3	31.0	30.7
43.0	43.4	58.8	55.3	50.0	49.4	25.0	25.4	22.0	18.5	31.0	30.4
46.4	47.0	43.0	44.0	33.0	40.9	37.0	37.6	33.4	34.4	30.6	38.5
77.4	74.7	65.0	60.7	43.4	46.9	33.2	30.5	35.6	31.3	49.6	53.1
51.2	51.7	73.0	69.6	60.0	61.5	37.0	37.5	29.4	26.0	38.0	39.5
48.0	51.5	62.0	62.3	59.0	54.9	33.0	36.5	36.0	36.3	22.4	18.3
42.4	46.9	59.4	60.0	49.8	55.7	38.0	42.5	30.8	31.4	28.4	22.5
59.6	63.6	47.0	49.6	51.6	52.7	29.0	33.0	53.0	55.6	23.8	24.9
50.4	47.1	56.0	53.9	43.2	40.2	31.0	27.7	34.0	31.9	33.4	30.4
65.0	68.1	65.4	63.3	53.0	56.7	38.0	41.1	34.0	31.9	49.0	45.3
51.0	55.8	45.0	46.4	44.6	42.6	31.0	35.8	26.0	27.4	51.2	49.2

Even with the system of correction given above, a slight error arises from the fact that the practice shortened the time for the latter trials; so that while the amount added or subtracted for the needed correction was estimated for the average time required for a trial, it would be somewhat too small for the longer first trials, and somewhat too great for the shorter last trials. But as the features of each curve are pronounced, this

correction would not materially affect them, this correction, if made, even in extreme cases not often exceeding a second.

Two typical curves illustrating the result from all the subjects are given in Fig. 6 from Sh. The first represents the sec-

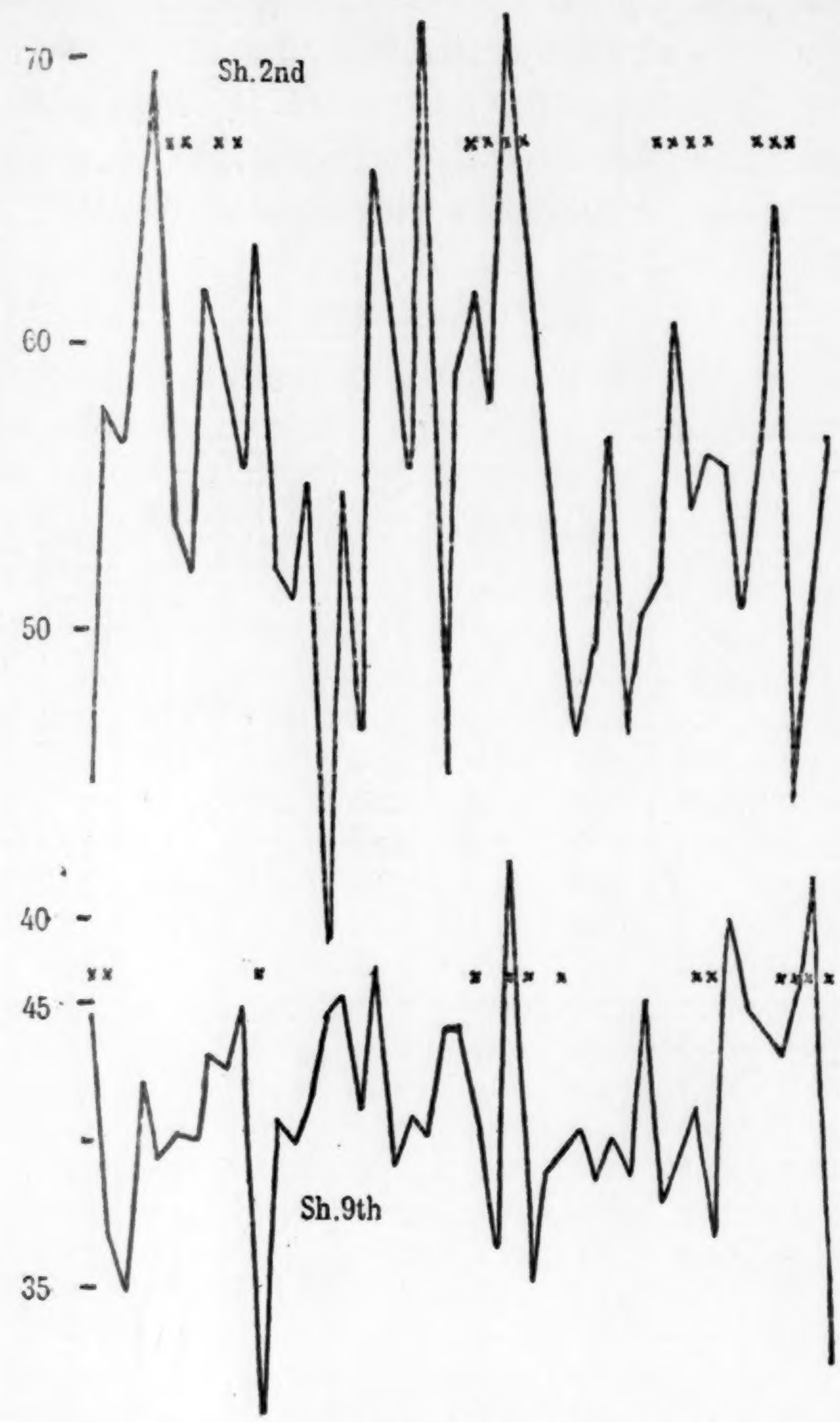


FIG. 6.

ond trial and the second the ninth. It is at once seen that there are great variations in the rate of adding, it being almost double for some columns what it is for others, and that these extremes are less marked in the later trials than in the first. In the first trials there are almost immediate transitions from the fastest to

the slowest rate, while in the later ones the medium rates occupy a much greater proportion of the curves. It almost never occurs that two successive points in a curve represent an extreme in the same direction. When several columns are added at a fairly constant rate they are usually followed by quickly alternating extremes. A general acceleration or retardation in one part of a curve is followed by a similar tendency of the opposite kind. A gradual tendency towards a fast or slow rate is often offset by one or two extremes in the opposite direction.

If these features are compared with the principles of exhaustion and recuperation found in muscular fatigue, it will be seen that they are covered by axioms 1, 3, 4 and 6 of the ergograph experiments, page 7. In short, there appears to have been a fairly constant and limited supply of energy that was drafted off, sometimes faster and sometimes slower, by means of this work. Perhaps the only feature found here that is not seen readily in the more common phenomena of fatigue is the frequent substitution of rapidly alternating extremes of function for a gradual loss of power. But this can be readily accounted for by the almost complete control offered by the experiment over the supply of energy used in the work, and by the nutritive conditions which allow rapid recuperation; more of which, later.

Careful examination shows no constant relation between the rate of adding and the mistakes. The dotted curves (Fig. 5) show also that there is no constant increase of mistakes for all of the subjects in any part of the trials. There is in each trial, however, a frequent tendency for the mistakes to be grouped.

Let us now turn to the subjective experiences.

The first trials without exception were very fatiguing, so much so that the work was dreaded. Then, after practice, it became gradually less so until it seemed but ordinary though active exercise.

As the methods of the experiment served to keep the objective conditions fairly constant, the variations in the results may be taken to indicate the subjective variations due to the work. So far as possible the subjective conditions were kept constant. With the exception of Ps., the same hour of the day was used

except for one change of time in each of the other subjects. This change coincided with no marked change in the record except in the case of Hn. But if the curves in Fig. 7, which

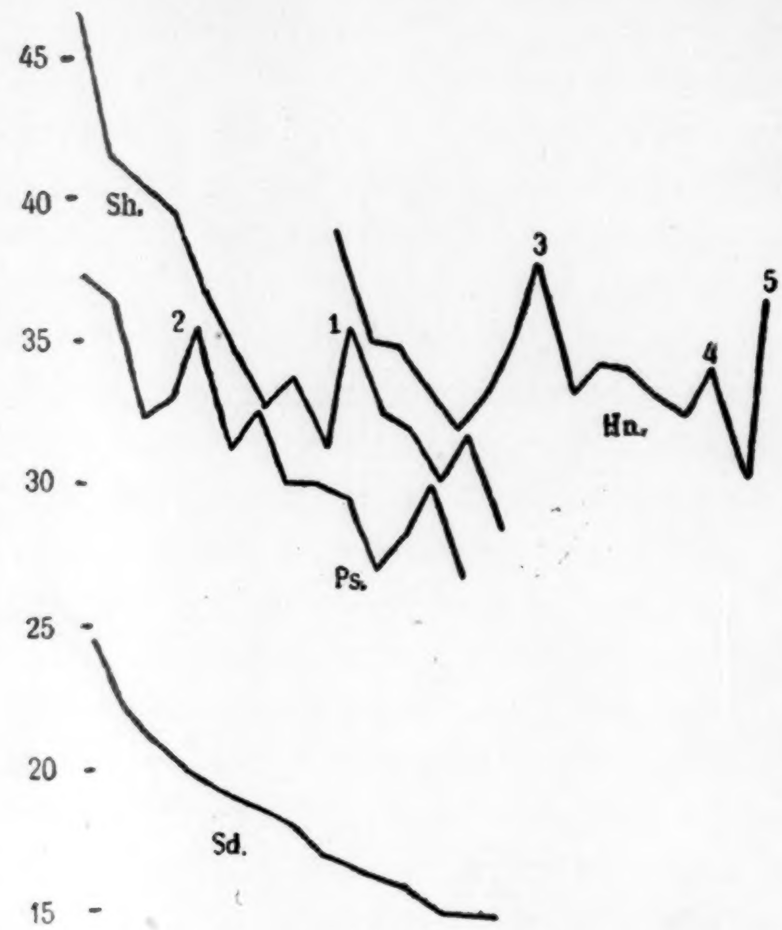


FIG. 7.

show the time effect of practice, are studied, the daily condition of the subjects — with the exception of Sd. — is seen to have varied considerably, as shown by the irregularity of the curves.[1] The unusually long times taken by some of the trials could not always be accounted for; when they could be, a general lazy feeling, the intrusion of extraneous ideas, and a feeling of fatigue from the work of the day figured most prominently. The shortening of the time, beside the effect of practice, seemed due to an unusual vigor. It is evident that better methods for controlling subjective conditions must be developed before anything like exact work can be done in experiments of this kind.

[1] The curves proceed from left to right and show the time of adding for the successive trials. The scale to the left denotes the time in minutes. 1. Not feeling well. 2. Unread letter in pocket. 3. First change from 3 P. M. to 9 A. M. 4. Subject felt lazy. 5. Fatigue with adding, to start with.

In turning to the conscious accompaniments of the periods of fatigue as shown by the curves for each trial, we find a variety of experiences. The very long periods shown by the curves (see Fig. 6 for illustration) may be caused in any one of three ways: first, by a suspension of the mental process in which the mind waits in a state of vacancy for the mental images used in adding to arise; second, by the displacement of the mental process by extraneous ideas, sometimes brought in by interrupting sensations; and third, by a confusion in the process of adding, frequently resulting in a mistake.

These disturbances would sometimes become prominent near the end of the trial, thus indicating a general fatigue, but more frequently they became prominent by the time the middle was reached and often before.

The suspension of mental activity is the same as that found in the last experiment. Voluntary effort is of no use in starting the process. There is a vacant feeling of suspense, and the subject is obliged to await the return of the mental images. This state may occur at almost any time in the trial—though not often occurring among the first few columns—and may be induced by unusual effort (axiom 1, p. 7). This vacancy may be filled by other ideas, and the subject brought to inhibit them in favor of the adding by means of the sensory and mechanical attitude which serves as a reminder. Often the ideas that fill up a vacancy in this way are of the most remote kind, and not connected by any conscious process of association with the ideas that preceded them. When some sensory stimulation interfered with the work, or when there was some interesting object in the background of consciousness, the degree of fatigue necessary for the rise of the irrelevant idea was much less; then it was accompanied with the feeling of intrusion. When the sensory stimulation was great, or when the idea in the background was of special interest, these conditions would evidently be of more significance in deciding what idea shall be uppermost in consciousness than the slight fatigue from adding.

It is thus seen how the first conscious reason for delay in adding gradually merges into the second, and this seems to merge equally well into the third, the confusion in adding which

results in a mistake. When, in adding, an extraneous idea comes to predominate in the mind, the image of the sum goes out. An ingenious way of retaining it comes consequently to be developed. The sum, up to the time of interruption, is automatically repeated with the vocal organs until the work is resumed, when the mental image of the sum is taken from the vocal expression. It is well known, however, that automatic processes are interfered with by vivid perceptual states. In this way the vocal repetition may be stopped by the intrusion, and the sum forgotten. A hesitation results from this, and the sum has to be guessed at or the column partly added over. The appearance of mistakes where the time for adding is short will be explained later. The grouping of mistakes (Fig. 6) seems largely due to the consciousness of having made a mistake, which acts as a distracting idea for the columns that immediately follow.

I believe the above description and explanation of the ways in which different ideas may displace each other apply as well to the experience of everyday life as to laboratory experiences. The familiar hesitating *-er* of a speaker, and ordinary absent-mindedness evidently find their explanation here, as also the rapid mind-wandering of the child.

Enough has already been said to indicate the tendency towards mental economy present in such a tedious process as adding. A close examination shows this to reach a high development in the variety of ways in which adding may be done. The object of this variety is probably to allow those centres employed in one way of adding to rest while those used in another way are exercised. At first the additions were made by combining one figure at a time to the sum immediately preceding it. This was when the process was slow and the rapid alterations in rate were very marked. After the first trial or two, two numbers would be combined, and later three before they were added to the preceding sum. One subject (Sd.) inhibited this tendency with great difficulty. Tens and twelves were favorite amounts to be made up and added in this way, though many others were used.

Another means of variety was the different ways two numbers could be thought of as combining. Suppose we have

fifty-six and eight to add. I can remember that six and eight make fourteen, and thus arrive at sixty-four; I can say fifty-six and four are sixty, plus four make sixty-four; or, I can say fifty-six and ten are sixty-six, less two are sixty-four. These might be combined in various other ways, but these serve to illustrate. Still another means of variety was a resort to a kind of primitive adding by emphasizing alternate units in counting on a number. The emphasis divides the number into groups of units while a kind of parallel reckoning tells when the groups are exhausted. In making the large combinations mistakes sometimes occurred, which accounts for the presence of mistakes with quick additions.

The curves in Fig. 7, which show the effects of practice, indicate a quick falling off in the time required for adding. The same addition sheets were used later in other experiments by three of the subjects, Sd., Sh. and Hn. The increased practice thus brought in reduced the time for adding in each case to less than half the time required at first. We are now in a position to ask how this was brought about.

If we look at Fig. 6 we find two significant points: First, while the mean variation of time-measurements is much less in the later trial than in the former, yet the absolute time is so reduced that the relative changes from column to column in rate for each trial are approximately equal. Thus the fastest time in the earlier trial is 39 seconds, and the slowest 71.5 seconds; fastest in later trial, 30.6 seconds; slowest, 50.1 seconds; $39:71.5 = 30.6:50.1$-approximately. Second, in the later trial there is a greater proportion of medium rates. These observations suggest that the effect of practice did not wholly consist in the development of economic devices which would tend to make the rate constant, but also in the power of holding mental images and the facility of using them.

The subjective records show that, other things being equal, practice causes the sums to spring up automatically and with great rapidity in response to the mental images of the numbers.

When an interval of several days came between successive trials it was found that the facility in adding was to some degree lost. The sums would not spring up so readily, and there was

a greater tendency to slower forms of adding. To test how far the particular combinations were remembered on account of the constant order of the figures, the addition sheets were reprinted with the order of each column exactly reversed. The following table allows a comparison of the time, in seconds, required for adding the inverted columns in three consecutive trials, with three trials of the normal order immediately preceding.

TABLE II.

	Sd.	Sh.	Hn.
Time before inverted order.	766.8 806.2 786.8	1633.4 1498.0 1478.4	1405.0 1345.0 1425.0
Time with inverted order.	868.7 794.5 812.0	1703.4 1649.4 1772.0	1490.0 1430.0 1407.0

As the work became more automatic the distracting effect of other ideas became less. Distinct and independent trains of thought became possible without materially interrupting the process of adding. Two subjects (Sd. and Hn.) had some of their brightest ideas come while adding, and sometimes extraneous problems would arise and be solved without causing confusion. When the full force of consciousness was needed to make combinations of numbers unusually difficult, it seldom failed to arrive at the proper time.

There can hardly be any question—at least in my own mind—as to where the attention was when the adding was going on automatically and the mind was solving some external problem, say in regard to finances. No doubt, frequent fluctuations occurred between the two; but there must have been—and the introspective record confirms this—considerable intervals in which the adding was entirely subconscious. The attitude of the mind towards the adding in such intervals may be called automatic attention, and may be said to have the same relation to sub-consciousness as attention proper has to consciousness.

But to call this automatic attention attention proper is a misnomer. It is also evident that sense organ adjustment was in this case with automatic attention, rather than with attention proper.

Experiment C.

The irregularity with which the mind works when confined to a narrow field of activity was also studied by means of nonsense syllables. Carefully selected nonsense syllables were arranged upon cardboard slips, ten syllables on each slip. Each slip was exposed for twenty seconds, during which time the subject learned as many as possible. The subject then repeated aloud as many as could be remembered, the number of correctly pronounced syllables being recorded by the experimenter. After an interval of seventy seconds another slip was exposed, and so on for a period of fifty to sixty minutes. The exposures and intervals were controlled by clockwork, and were therefore constant.

There were three subjects in this experiment, two of which (Gy. and Ly.) had had long practice in similar work, and could therefore memorize much more easily than the other.

Considerable irregularity was found in the power to learn the different slips, but there was no way of making the work necessary for learning the different slips equal, as was possible in the work of the last experiment. The experiment, therefore, was not continued for a long time. The following table gives the number of syllables correctly learned in each successive slip in a sample trial by each of the three subjects. The variations from slip to slip seemed principally due to the variation of subjective conditions, although Gy. was not consciously affected by fatigue and seemed to remember the syllables in direct proportion to the facility with which he could make associations with them. He was unusually proficient in this; and although the syllables were selected with a view to excluding associations, the results taken from the other subjects are also probably affected to some degree by this. Ly. found himself resorting to artificial means for memorizing at the ends of the periods, such as pretending surprise at some of the syllables. At such times the fatigue was very marked. This, with the fact that Gy. did

not feel fatigue with his elaborate system of associations, seems allied to the introduction of variety in adding in the last experiment. With Ly. no explanation could be given by him of the variations of proficiency except an infrequent association. To him the experiment was fatiguing only when the interval of seventy seconds was considerably decreased. Gy. was not affected by this.

TABLE III.

NUMBER OF SYLLABLES CORRECTLY LEARNED.

	Ly.	Gy.	Lr.		Ly.	Gy.	Lr.
1st slip	8	9	6	18th slip	6	8	4
2d "	5	10	5	19th "	7	8	4
3d "	8	8	5	20th "	4	6	4
4th "	7	10	6	21st "	9	9	3
5th "	9	9	3	22d "	5	7	4
6th "	8	9	6	23d "	6	10	5
7th "	8	6	4	24th "	8	9	3
8th "	9	9	3	25th "	6	10	4
9th "	7	10	3	26th "	7	7	2
10th "	7	10	3	27th "	4	7	4
11th "	9	10	4	28th "	7	7	4
12th "	8	7	3	29th "	6	9	2
13th "	8	10	3	30th "	6	10	5
14th "	8	7	5	31st "	6	10	2
15th "	5	4	4	32d "	4	9	5
16th "	7	4	3	33d "	3	10	5
17th "	6	5	2	34th "	5	7	6

Experiment D.

It will be remembered that in Experiment A there was an intensity of the alternating current of electricity found which stimulated the power of attention, and that reading aloud had the same effect upon Hh. Also that reading aloud to Sh. and Hn. caused confusion. In Experiment B it will also be remembered that with all the subjects (Hh. was not in Experiment B) fatigue was most frequently shown by the presence of disturbing ideas, and that noises and entertaining ideas would cause disturbance without distinct fatigue. The object of Experiment D

was to study farther the influence of a sensory stimulus upon mental activity.

The subjects were Sh., Hh. and Hn. The work used to test the constancy of the attention was the addition sheets used in Experiment B. The stimulation used was an alternating current applied by wet cloth electrodes bound firmly to opposite sides of the left wrist. The intensity of the current was adjusted by the subject to what seemed to have the most beneficial effect upon the work. In other respects the experiment was conducted as Experiment B.[1]

With Sh. five trials were taken with normal conditions and these were followed by five with the electric stimulus. These were again followed by two trials with normal conditions. With Hn. five trials were taken when the electric stimulus was used, each of which was followed by a trial under normal conditions. In the case of Hh. the same method was followed as with Hn. except that another kind of distraction in the form of a music-box playing consecutively ten popular airs was introduced, thus enlarging each group of trials to three. Sh. and Hn. afterwards used the music-box with four trials, alternating each time with a trial under normal conditions. The following tables (IV. and V.) give the time for each trial in seconds.

There are certain prominent features found here. It is seen that with Sh. (Table IV.) the time required for the trials with electricity is less than that for the trials preceding them, with the exception of the one immediately preceding, but greater than those which follow. This evidently shows the effect of practice even at this late stage, but also an accelerating effect of the stimulus at first, and a relatively retarding influence later.

This is shown much more distinctly with Hn. Here, where there was an alternation between the normal trial and the trial

[1] After Experiment B was finished it seemed desirable to determine whether the transition from one column to another and from one sheet to another had introduced sufficient distraction to affect the results of the experiment. Accordingly, a set of the sheets was arranged with the columns running continuous in tape fashion, in the same order which they had been added in Experiment B. Six tests upon each of three subjects (Sh., Sd. and Hn.) showed no distinct effect, except such as would naturally result at the first two or three trials from any new arrangement. This tape, instead of the sheet arrangement, was used in Experiment D.

with electricity, a striking difference is at first seen in favor of the electricity, and as striking a one seen in favor of the normal later. The last normal trial is shorter by 716 sec. than the first; while the difference between the first and last of the trials with electricity is but 290 sec.

In the case of Hh., there had been no practice in adding before this experiment was begun, although the rate was much faster than in the other two cases. Here the adding was throughout faster with the electricity.

The stimulus, therefore, had a distinctly accelerating effect upon the adding at first; and in two out of the three subjects, a distinctly retarding effect later.

TABLE IV.

Hh.			Sh.		Hn.	
Normal.	With Elec.	With Music.	Normal.	With Elec.	Normal.	With Elec.
951	808	750	1787		2121	1899
707	675	683	1701	1576	1992	1852
730	673	688	1700	1537	1576	1615
680	612	684	1641	1584	1564	1721
706	655	663	1529	1605	1405	1609
				1568		
			1528			
			1522			

Table IV. shows the time for adding with music for Hh. It is seen that the effect was an acceleration over the normal, but a retardation compared with the electric stimulus. Table V. gives the effect of music on Sh. and Hn. With Hn. the effect was first to retard, while with Sh. it accelerated the adding. It should be said, however, that Sh. took the record of Hn. the day before the first trial of Sh. was taken, and that the presence of the music was so disturbing as to make the taking of the record almost impossible. Afterwards it had but a slight effect.

It is interesting to note the influence of these stimuli upon the curves which represent the time measurements for each col-

umn as in Experiment B. In Fig. 8 are given two curves from Sh., one normal and one with electric stimulus. The time for the former trial was 1641 sec. and for the latter 1576 sec. In spite of the decrease of time the stimulus is seen to have made the curve more irregular, to make greater extremes in rate, and

TABLE V.

Sh.		Hn.	
With music.	Normal.	With music.	Normal.
1499	1531	1498	1338
1380	1509	1400	1289
1401	1362	1294	1227
1390	1520	1274	1320

to make them follow each other more quickly. In Fig. 9 are given two curves from Hn., one normal and one with music. The time for the normal one was 1338 sec., and for the other 1498 sec. At this trial the music was extremely distracting to the subject, causing an emotional state comparable to that of exploding wrath. Here the effect is also to increase the irregularity of the curve, with also an increase in the proportion of long periods. The curves in both these figures are strictly typical. They were corrected according to the second system of tabulation in Experiment B, and since practice had considerably shortened the time, the further correction for the effect of practice not applied in Experiment B was used here.

With Sh. the electricity decreased the number of mistakes, while the music increased them. With Hn. the electricity increased the mistakes and the music decreased them. With Hh. the mistakes were about equal for the two stimuli, but they increased forty per cent. for the normal.

The conscious effect of the electricity upon the subjects was to stimulate and strengthen the mind, and to keep away distracting ideas. With the exception of the later trials of Hn. it did not seem a distraction. In the first trials of Hn. it seemed

to fill in the voids and make the time pass more agreeably. For him the fatigue after the trial seemed less when electricity was used. A few instances in which the current was unusually strong, with all the subjects, marked trials in which the time for the adding was exceptionally short and the mistakes few. The only exceptions to this were the later trials of Hn. Practice with the current appeared to make the subjects less conscious of it.

With Sh. and Hn. the music was at first extremely distracting and produced a high degree of iritability. Sh. added nearly aloud the first time, evidently to keep the mind from wandering. An effort was also made to add as rapidly as possible in the short intervals between the tunes. Sh. also tended to fall into the time of the tunes, was accelerated by quick ones and retarded by slow ones. About three-tenths of the whole round of ten tunes were too slow for this subject. They were all played through between four and five times for Sh. and Hn. Hh. was not much affected by the music, and Hn. and Sh. were not after the first time, except that in the case of each it made an agreeable interlude.

The first effect of the music was evidently similar to that of disturbing ideas and sensations in Experiment B, in which we found that these caused long, upward sweeps of the curve.

There are at least three theories that might be advanced to explain the effect of the electricity. One is that of the reinforcement of sensation, a typical illustration of which is the power of seeing an otherwise invisible object by means of a vibrating tuning-fork held at the ear. Here the adding would correspond to the visual function, and the electric current, to the tuning-fork. But this theory would not tell us why the electric current and the music had a different effect later.

Another theory might be that the stimulus acted as a reminder, thus causing a more constant effort on the part of the subject. In support of this it may be truly said that the subject sometimes was conscious of hurrying to get through quickly and avoid the pain. However, this theory would not explain the negative effect of the current, as shown by the latter part of the records of Sh. and Hn. Besides, a special effort usually brings an enforced pause.

It has already been noted that in adding without an electric stimulus there is going on a more or less constant fluctuation of the attention to other ideas. This seems to show the necessity of a frequent fluctuation due to the fatiguing of the adding function. What is required, therefore, seems to be a rest, and the way it can be obtained the most economically will assist the adding function most. In this experiment it was observed that the presence of the electric stimulus in consciousness tended to keep other ideas from intruding.

Professor Mosso states for muscular fatigue that when 30 contractions of a muscle bring about complete exhaustion, thus making a rest of two hours necessary for complete restoration, 15 contractions, or one-half the number, cause a fatigue which is recovered from in half an hour, or one-quarter of the rest needed for complete exhaustion.[1] In other words, the greater the exhaustion the slower is the rate of restoration. It is also stated by Professor Kraepelin that mental fatigue is more slowly recovered from the greater its degree. Thus it is found that school children need more frequent and longer pauses for rest as their fatigue becomes greater, in order to keep in good working condition.[2] The frequent interruption produced by the current in Experiment D would therefore bring rest when it could be used to the best advantage, before extreme fatigue had set in.

Still another important factor may be that so uniform an activity as that of attending to an alternating current does itself quickly tire, causing a quick return to the primary occupation. Herein probably lies the reason for the different effects produced by the electricity and the music. The music gave a succession of inviting ideas suggested by the notes holding the attention longer than was needed for rest.

It may now be asked how this theory accounts for the later negative influence of the electricity. It may be seen that in both cases (Sh. and Hn., Table IV.) where this negative influence was found, the practice had reduced the time needed

[1] 'Die Ermüdung,' p. 151.

[2] See extract from address published in *Popular Science Monthly* for October, 1896, p. 760.

for adding the sheets, under normal conditions, to much less than what it formerly was. With Sh. this had largely come before Experiment D, but with Hn. it came principally in this experiment. This and the increased evenness of the normal curves (Figs. 8 and 9) show that the power for constant adding

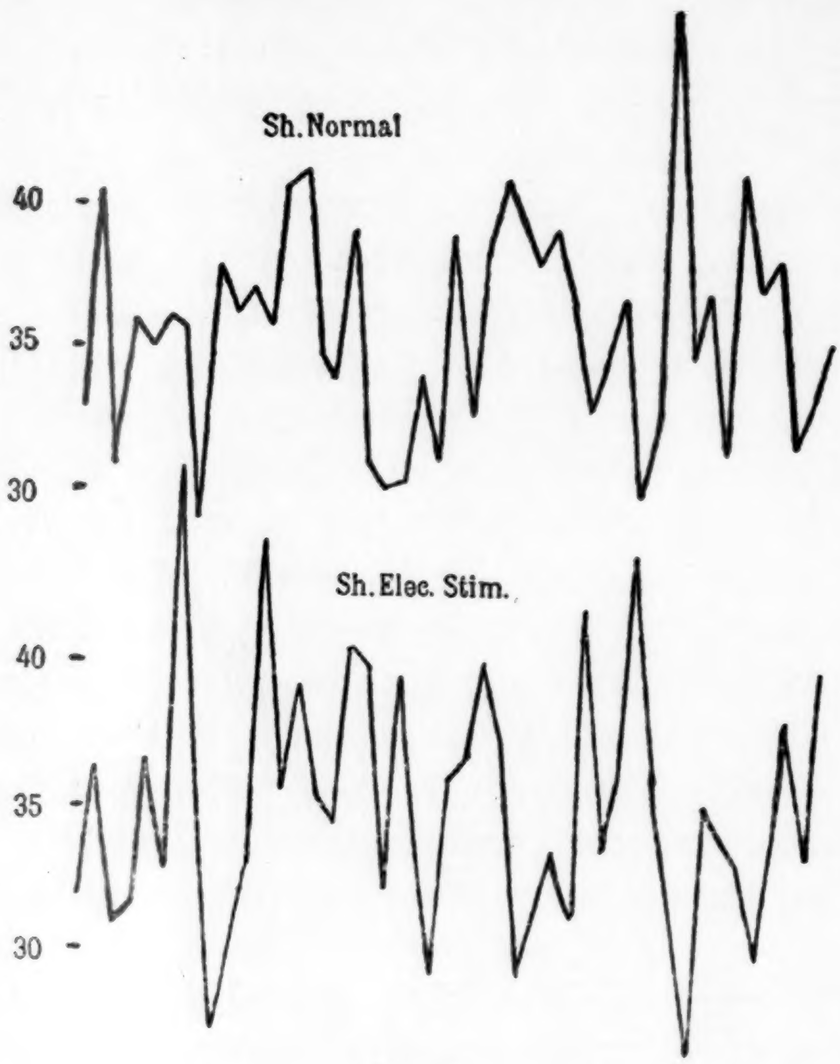


FIG. 8.

had greatly increased. This evidently means that the supply of energy for the adding had come to equal more nearly the demand. Hence the intrusion of an idea when the function for adding had not become fatigued would be a hindrance rather than a help. In other words, the power of adding had become too strong to profit by so frequent rests as were imposed by the current.

Another experiment may as well be spoken of in connection with this, as its results were of a similar kind. Sh. and Hn. tried the effect of adding the sheets under normal conditions except

that a special effort was made to avoid mistakes in the sums, even at the expense of time. By comparing these trials with those preceding and succeeding, the time for adding was found to have an average increase of 131 sec. for Hn. and 123 sec. for Sh. The number of mistakes made in these trials was slightly decreased for Hn. and slightly increased for Sh. Both subjects were disturbed and confused by the attempt.

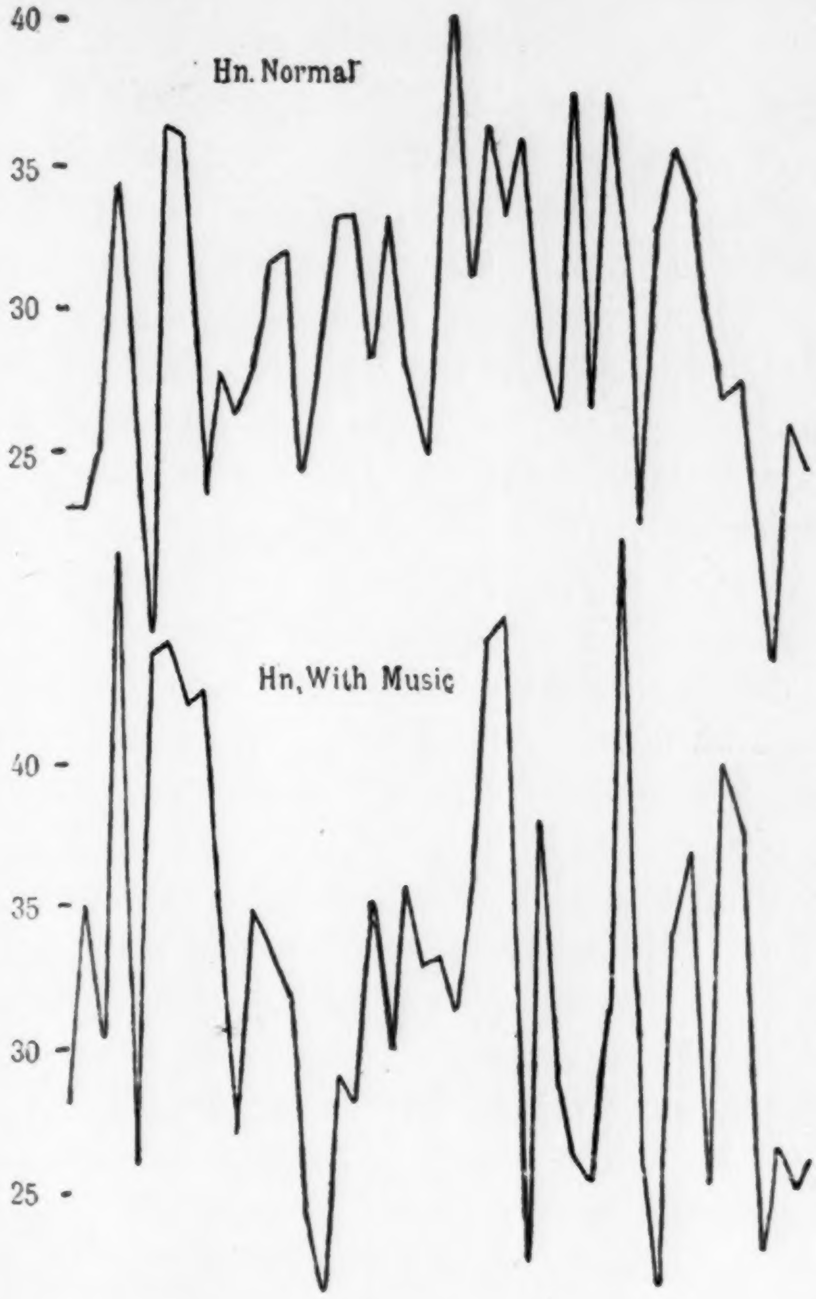


FIG. 9.

It is evident that Experiment D is unsatisfactory, since it raises an important point, but gives only a meagre amount of data: more subjects should have been used, and the work carried farther with each. There is hardly a chance for doubt,

however, that what would naturally promise to be a distraction to a mental process may be of assistance. This is also borne out by the late work of Dr. Hamlin already referred to.[1] In this it was found that the power of correctly comparing distances, determined by the position of paper squares arranged upon a black screen, was increased by the subject's adding at the same time.

Experiment E.

Experiment E was planned to test the degree of independence of different mental functions, and also to show whether the exhaustion of a function at one time would be felt later, as is well known to be the case with extreme muscular fatigue.

A large black cardboard screen was fixed in a vertical position upon a table so that the light from a window would fall directly upon it. The part of the table between the window and the screen was also covered with black cardboard. In the middle of the vertical screen was an opening 6 centimetres square, on the level of the eyes of a person when seated. Behind the opening was fixed a slide for holding cards. The subject was placed 45 centimetres from the screen with the hand resting in an easy position upon an electric key which controlled a marker at a kymograph drum. Another marker registered seconds; the drum revolved once in 30 seconds. With the eyes of the subject so turned to a black square lying upon the table as to make a visual impression from the screen opening impossible, a diagram or picture was placed in the opening of the vertical screen. The experimenter gave a signal and the subject looked up, his fingers pressing the key as his eyes fell upon the picture. This was looked at as long as there was a natural inclination for the subject to do so. When through looking, the eyes went again to the black square, and the fingers allowed the key to rise, thus giving a signal to the experimenter. After an interval of 15 seconds from the rising of the key, another picture was looked at in the same way. Before each series one or two practice pictures were given, and the order of the pictures was always changed.

[1] *Am. Journal of Psychol.*, Oct., 1896.

Each subject was practiced in the mechanical parts of the experiment to make them as automatic and unconscious as possible. As is evident, the object of the apparatus was to register the exact time—to tenths of seconds—which each picture attracted the attention of the subject. There were ten pictures in all, lettered roughly in the order of their complexity. These were selected from the stereoscopic views for giving optic illusion prepared by J. Martins-Matzdorff.[1] The letters corresponding to the original published numbers are as follows: A, No. 18; B, No. 11; C, No. 13; D, No. 5; E, No. 14; F, No. 1; G, No. 15; H, No. 3; I, No. 7; J, No. 10. The right sides

TABLE VI.

Picture.	A	B	C	D	E	F	G	H	I	J
Mar. 10	2.2	4.2	4.9	9.4	10.3	12.9	26.8	18.6	23.4	10.7
" 11	1.9	3.2	4.8	2.4	8.6	11.5	18.1	9.7	20.9	7.2
" 13	1.7	2.7	3.3	1.9	8.4	11.9	3.2	9.7	23.0	12.5
" 16	1.8	1.2	2.7	4.1	77.6*	14.6	28.0	6.3	22.3	8.5
" 17	1.9	2.5	2.4	2.6	12.8	7.8	18.7	10.7	20.6	9.0
" 18	1.5	2.5	2.3	2.4	3.6	28.3	26.3	11.4	28.5	15.3
" 19	2.7	2.2	2.5	3.9	5.6	12.1	22.5	7.3	28.6	18.0
Apr. 24	4.0	2.9	2.3	3.9	4.0	10.1	119.9*	12.5	21.2	11.1
" 25	1.4	3.9	7.0	2.1	4.4	15.7	8.8	5.2	9.3	6.7
" 27	83.6*	5.4	4.0	6.3	7.9	19.9	12.9	8.3	20.2	4.6
" 28	1.3	5.1	1.2	——	1.8	3.3	4.5	2.3	8.0	6.7
" 29	.9	2.7	4.6	2.8	3.0	10.7	3.8	9.0	9.2	5.6
" 30	117.6*	3.0	129.5*	8.5	3.3	2.5	1.5	10.6	9.0	3.0
May 2	4.0	4.0	9.3	4.1	5.0	10.4	6.0	3.0	10.3	6.0

The stars denote times when the subject was required to look longer than he naturally wished to.

only of the pictures were used except in the cases of Nos. 3 and 10, in which the left sides only were used. A to D were geometrical figures; E, concentric circles of different shadings; F, a Greek head; G, diagram of engine piston; H, silhouette of tree and gateway; I, Prometheus bound; J, colored waiter in anteroom.

The artistic value of the pictures also varied considerably. The pictures were shown at the same hour on consecutive days,

[1] Wickelman & Sons, Berlin, 1889.

and the time for each picture recorded for each day. There were, however, breaks in this regularity due to Sundays and other occasional interruptions. Five subjects in all took part in this experiment. Cl. saw the series of pictures 26 times; St., 20; Dn., 19; Hn., 12; Cs., 9. Table VI. gives the first and the last parts of Cl.'s record, which, in general, illustrates the others. The numbers give the time in seconds for each picture.

Although all the pictures were of a very simple type, the more complicated ones being hardly more than outline drawings, there was yet a very marked difference of time given to the more complicated ones as compared with the simplest; and this difference is preserved throughout the experiment, even after the views had become very familiar and the time for looking at them greatly decreased. Table VII. gives the average time

TABLE VII.

	A	B	C	D	E	F	G	H	I	J
Cl.	2.5	4.1	4.0	4.1	6.7	12.9	16.4	9.1	15.8	10.1
Dn.	7.4	6.8	8.7	8.5	10.5	10.3	9.1	8.4	11.6	8.6
Hn.	2.1	2.7	3.5	7.0	9.0	15.8	24.4	16.1	22.9	15.9
St.	19.5	17.4	21.4	28.6	30.0	36.6	33.4	37.6	41.0	43.7
Cs.	1.4	1.3	7.8	1.1	1.9	4.9	2.5	3.4	7.7	5.7
Final av.	6.6	6.5	9.1	9.9	11.6	16.1	17.1	14.9	19.8	16.8

in seconds devoted to each view by the different subjects.[1] This phase of the experiment evidently touches upon the objective conditions for holding the attention in one direction. This experiment in itself suggests that, while the mere complication of a figure is an element in this, there are yet other important factors.

In Table VII. it is seen that there is a great difference in the time given by the different subjects to the views, and also that a picture will attract one subject a greater relative length of time than it will another. I believe we here have a method that

[1] The tables showing averages do not include the time for the unnatural holding of the attention on the views to be described later.

might be of great value in finding out not only what naturally attracts the attention, but also personal differences of mental aptitudes. While picture J was by far the most complicated of the series, picture I, of Prometheus, is seen by the final average to have had the most attractive power. If one introspects carefully while looking at a picture, a multitude of half-conscious associations are found to jostle one another along at an irregular pace, thus composing his 'stream of consciousness.' Some pass very quickly and seem to form an interlude or 'fringe' for those which linger longer and furnish more substantial perches for the attention to rest upon. Often one of these longer stops, or where the stream moves very slowly, is accompanied by a vague feeling of enjoyment when the cause cannot be understood. Perhaps more commonly one is keenly alive to the features which hold him captive, and is able to give the reason for their hold upon him. This vague attractiveness was especially prominent in the cases of the Greek head and Prometheus —those pictures of the most artistic value.

Table VIII. gives the average time in seconds spent upon a view (for each subject) at successive trials. This shows how the time varied with succeeding days. The numbers in the column at the left of each record give the number of the day for each trial, numbered from the day of the first trial. This is to show when days came on which the experiments were omitted. With Cl., St. and Hn. there is a falling off in the time after the first trial, and a gradual increase after this. Then comes a final decrease of time.

It would be interesting to know what causes this increase. If it were not that the subjects were told to inhibit all associations—which, however, could not be strictly carried out—it would seem possible that new associations came to cluster about the views more and more. It may be that associations which were half conscious at first, or altogether unconscious, became later through the repetitions to be more conscious and thus gave an added complexity to the views. These newly made conscious elements would naturally become less and less attractive, and as the picture would have a limit to its suggestiveness, would allow the time finally to fall off.

TABLE VIII.

No. day	Cl.	No. day	Dn.	No. day	St.	No. day	Hn.	No. day	Cs.
1	12.3	1	7.4	1	24.0	1	9.9	1	5.4
2	8.8	2	9.1	2	22.0	2	6.9	2	6.3
4	10.7	4	8.6	3	17.5	3	14.3	3	4.3
7	9.9	5	8.0	4	28.4	5	7.6	4	3.5
8	8.5	8	7.7	7	32.6	6	13.8	11	6.3
9	9.6	9	9.8	8	46.6	7	20.3	13	2.3
10	10.5	11	8.3	9	38.0	8	17.8	14	1.1
14	17.2	12	9.2	10	55.5	9	9.2	17	.9
15	19.7	13	8.3	11	49.7	10	15.0	17	.4
16	13.6	14	9.6*	13	36.0	14	8.8		
19	8.7	15	7.5†	14	21.5	15	14.7		
21	5.7	16	8.5†	15	52.9	15	11.4		
22	6.3	25	8.6	16	43.3				
23	13.4*	26	9.2	17	28.3				
24	3.4†	28	8.2	18	11.8				
25	4.9	29	10.5	20	18.4				
26	4.8	33	9.1	21	19.2				
45	8.0	34	13.4	23	17.5				
46	6.2	35	15.2	24	22.1				
47	9.9			24	13.5				
49	4.1								
50	5.2								
51	5.7								
52	6.1								
54	6.6								
55	5.6								

Although there is a comparative distinctness in the difference of time given at each trial to the different pictures, as shown in the sample of Table VI., and still more in the averages in Table VII., this distinctness is by no means constant. Thus, while (Table VI.) *A* is generally less attractive than *B*, sometimes it is more so. This seems to show that the subjective valuations of the different views are independent and that a general increase or decrease of time is not dependent wholly, at least, upon some general cause influencing the whole series, like an unusual buoyancy or depression of spirits. If the cause suggested for the general increase of time given to a picture be true, it is

* The intervals between the pictures in this trial were filled with adding.

† The intervals between the pictures in this trial were filled with looking at magazine pictures.

natural to suppose that the increased or decreased valuation would not go on at exactly the same time in the different pictures.

Doubtless, however, there are many factors that have been overlooked as well as uncontrolled; therefore, to give a better test for the separation in the functioning of different mental activities for different views, a modification of the above experiment was resorted to. If we regard the capacity for enjoying one picture as exercising a mental function comparatively independent of that used for another picture, then if the time is lengthened beyond the natural limit of enjoyment, a fatigue would naturally result which would shorten the time for enjoying that particular picture at the next trial; providing that nutritive processes had not placed that function in its first anabolic condition.[1] Accordingly, at different trials views were selected to which the subject was required to give close attention for a period of time controlled by the experimenter. All associations were inhibited so far as possible, although Dn., Cl. and Cs. were unable to do this satisfactorily. Table IX. gives the record of these trials in seconds in their order. The figures in heavy type give the number of seconds the subject was required to keep the attention confined to the view, while the numbers above these give the time the view had naturally attracted the attention on the two preceding trials, and those below the time it attracted the attention at the succeeding trials. As a rule the simpler views were taken for this. The letters at the top of each column tell the particular view.

The effect of this is seen to vary. Often the effect of the first trials was to increase the attractiveness of the view, bringing out many new minor points even after the views had been looked at many times. With two subjects (St. and Hn.) distinct aversions or passive dislikes often appeared for the view in the trials succeeding those of the long periods, even when the subject had forgotten what view had been looked at in this

[1] It is evidently incongruous to speak of mental functions as being dependent upon anabolic conditions when psychoses have not been proved to result from neuroses. It has been shown, however, that the functionings of the two are controlled by similar if not identical laws; so that while the terms applying to one may not apply fully to the other, yet they are at least convenient figures of speech.

TABLE IX.

	E	B	C	F	A	A	C	C	J	
	8.6	2.5	2.2	11.8	4.0	1.3	1.2	4.6	3.0	
	8.4	2.2	4.9	12.6	1.4	.9	4.6	9.3	6.0	
Cl.	**77.6**	**68.0**	**125.0**	**119.9**	**83.6**	**117.6** *	**129.5** *	**115.0**	**240.0**	
	12.8	10.2	1.9	8.8	1.3	4.	9.3	3.0	20.0	
	3.6	32.4	7.3	12.9	.9	3.				
	E	C	A	C	E	F	D	G	A	B
	15.2	8.0	7.4	8.7	7.4	10.0	8.0	11.9	7.3	10.1
	10.1	10.1	8.0	6.0	10.0	13.8	8.4	10.1	9.4	7.6
Dn.	**46.1** *	**122.0**	**78.2** *	**77.7** *	**83.2** *	**72.6** *	**55.0**	**47.8**	**85.1**	**82.4**
	10.8	8.0	7.3	5.5	10.4	7.0	9.6	10.8	7.3	12.6
	7.9	9.5	9.4	11.6	12.0	10.3	12.0	7.3	11.5	8.7
	A	D	D	C	D	A	H	H	D	I
	17.7	15.2	41.0	46.0	14.0	17.0	28.0	11.0	19.0	28.0
	11.0	21.0	59.1	46.0	75.0	8.0	11.0	14.0	24.0	16.0
St.	**115.4** †	**42.8**	**180.0** †	**180.0**	**240.0** †	**60.0** †	**240.0**	**240.0**	**120.0**	**180.0**
	14.1	32.0	21	28.0	8.0	6.0	14.0	25.0	12.0	14.0
	13.0	41.0	31	52.0	10.0	7.0		25.0		
	C	A	C	A	I	D				
	1.6	1.5	2.5		11.0	11.0				
	3.4	1.9	7.9	1.6	46.8	3.0				
Hn.	**46.1**	**191.6** †	**111.2** †	**52.0** †	**240.0**	**278.0**				
	2.5	1.6	5.0	2.0	1.0	2.5				
	7.9		1.9	2.3	5.5					
	C	C	A	I						
	2.9	.6	1.0	5.3						
	1.6	33.8	3.0	1.2						
Cs.	**44.0**	**42.0**	**189.0** *	**51.9**						
	.6	1.9	1.2	.6						
		.8	.5							

Those marked with a star were not followed by a trial on the succeeding day. A dagger marks the cases which were followed by distinct distaste.

way. Cl., Dn. and Cs. felt no distinct differences in the succeeding trials from this enforced attention, though all but Dn. and Cs. felt fatigue from the effort at the time. These continued to see so many new things in the views and had such imperative associations that the attention could not be kept fixed. It is interesting to note that St. and Hn. were the only ones successful in inhibiting associations, and also were the only ones who felt the distinct distaste in the trials following the long periods. Evidently the rest which came from the variety in the associations had to be eliminated to make the effect of the fatigue lasting.

There were very distinct emotional states accompanying this experiment. Beside those vague feelings of recognition already described, there were those of active enjoyment which usually accompany the looking at pictures, and which gradually grew less as the series was repeated. There were also the feelings accompanying fatigued functions peculiar to the modification of the experiment just described. We have seen in Experiments A and B that a degree of fatigue is easily reached which makes constant work impossible. In the present experiment we seem to have the natural emotional accompaniment of that condition. The milder stages of it are shown by a lack of response to the object on the part of the subject. There is the feeling of, *there is nothing in that for me.* It is like a dry mouthful of something that cannot be masticated. This stage gradually merges into that in which the object is positively distasteful or repulsive. This is often tinged with a kind of sickening dread, comparable —if I may carry the illustration still further—to the feelings accompanying the eruptions of a rebellious stomach. One subject said the sight of the object caused him to shudder and to say impulsively, "Take that out."

A similar experiment was tried on St. with the music-box used in Experiment D. Each tune was repeated at the first trials as long as the subject wished it. At later trials a tune would be repeated several times after the subject wished it stopped. At first this seemed to increase the attractiveness of the tune, as was the case with the views. After several trials of this kind, however, the repeated tune caused the same revul-

sion and shudder that was noted with the views. The experimenter had a distaste for the repeated tunes even before the subject.

In this last phase of the experiment there appeared more distinctly than before those vague feelings of enjoyment noticed especially with Prometheus and the Greek head. Such feelings seem to merge gradually into the more definite associations which accompany recognition, and these associations in turn branch out in new directions suggested by the object recognized, whether it be a tune or picture. No definite line can be drawn to divide the different stages of this process. It may be of significance that these variously branched associations have the same effect of prolonging the natural time for attending to an object that the variety in the ways of adding introduced into Experiment B had in making the rate of adding more constant; and that the complexity of an object has the same effect. The evidence from these observations seems to indicate: first, that an object of attention holds its ascendency in the mind longer (*a*) because of its complication or variety of elements; or (*b*) because of the associations formed with it (this last would include its æsthetic value); and second, that the process and irradiations of thought are to a considerable degree controlled by fatigue; since the inhibition of them seems to result in the excessive exhaustion of some mental function. If this is true, it is evident that the more volition there is employed in attention the more the equilibrium of the mental activity is disturbed.

A source of inaccuracy in this experiment was the inability of the subject to give an exact limit to the time during which he wished to look at the views. It was easy to tell when that time was not nearly expired, and when fatigue had definitely set in, but since one shaded into the other gradually, no exact line could be drawn between them. When the mind was in a torpid state this transition was much longer than at other times; and it was longer with some subjects than with others. In general, it may be said that the longer the time a view was naturally looked at, the longer was this transition period. The relative error would, therefore, be fairly constant. With the longest times this usually was not over five seconds, and for the shorter not over one-half a second.

Experiment F.

Experiment F was designed to make a still further test of the separation of mental functions. On one day the subject added as rapidly as possible the addition sheets of Experiment B, twice in succession. On the next day nonsense syllables were learned for a period of time equal to that required for adding the sheets the first time on the first day, and this was immediately followed by adding the sheets once. On the third day the sheets were added twice again, and so on. The same nonsense syllables were used as described in Experiment C. In Experiment F, however, each slip was studied until it could be repeated correctly before another slip was learned. Usually five or six slips were learned in the time allowed. Complete records were taken from two subjects only, Sd and Hn. The former added the sheets twice in succession ten times, and added the sheets preceded by the syllables ten times. The latter did this but five times. The following table gives the results. The work was done at the same hour each day in the case of both subjects.

TABLE X.

	No. of Trial Group.	Time for adding Sheets twice in succession. First Time.	Time for adding Sheets twice in succession. Second Time.	Time when adding was preceded by syllables.
Sd.	1	1038	1094	921
	2	921	929	892
	3	.922	998	875
	4	928	984	819
	5	912	922	871
	6	925	975	903
	7	889	935	815
	8	915	960	869
	9	872	918	870
	10	867	926	859
Hn.	1	1203	1282	1088
	2	1172	1296	1104
	3	1184	1173	1028
	4	1077	1109	1051
	5	1055	1095	1014
Totals.		14880	15596	13979

It is seen by this table that the number of seconds for adding the sheets the second time, when the adding was immediately repeated, was considerably greater than for adding the first time; and that the time for adding the sheets after the syllables had been learned was less than that for adding the first time by an even greater difference. There is no exception to this rule. Another subject (Lr.) was started upon the same experiment and showed the same features in his result, but, as the work was not long continued, the results are not given. The following record of mistakes made in the adding is seen to be in perfect accord with the time measurements.

TABLE XI.

		Sd.	Hn.
Whole number mistakes in adding sheets twice in succession.	1st time	42	55
	2d time	53	60
Whole number mistakes in adding sheets when preceded by syllables		30	38

So far as the subjects were conscious of the effect of learning the syllables upon the adding, it kept the mind freer from extraneous ideas, and gave an agreeable change in turning from the syllables to the adding. These tables show not only that the adding function was not fatigued by the learning of the nonsense syllables, but that its power was materially increased. The learning of nonsense syllables may be supposed to exercise but a limited range of mental activity, and thus keep the attention from innervating the store of energy used for a different kind of activity, more effectually than would involuntary musing. That this increase of power was not due to a general 'warming up,' or to increased excitement, is evident from the fact that when the sheets were added twice in succession the second adding was slower; and also that at several trials when the pulse was taken before and after the work it was found always to be slower at the end. The emotional effect of changing from the syllables to the adding was also typical of the activity of a high anabolic condition for the latter. This experiment, therefore, very strongly confirms the theory set forth

above. It also contains a suggestion for a method of controlling subjective conditions for experimentation. If the confining of the attention to one mental function causes another function to be supported by an amount of energy which, when discharging, excludes all irrelevant ideas that would otherwise be a distraction, then such a device for conditioning a function to be measured would doubtless be of considerable value.

It is not only towards objects of attention over which we try to fatigue ourselves that we find changes of mental attitude taking place. We seldom have difficulty in sitting down to the dinner table to decide what dishes are best suited to our appetites; and we also notice that what would be enjoyed one day might be nauseating on another. Our intellectual enjoyment of the different objects of our attention is in many ways similar to this. It is not difficult at any time to tell whether a certain mental activity (such as the rehearsal of a poem, or the recollection of a past experience) would be enjoyable or otherwise. And it often occurs that we have a feeling of satisfaction after such an activity comparable to that feeling of contentment which follows a good dinner.

Experiment G.

In Experiment G the data consist chiefly of emotional records and are made up of experiences like those first cited in the introduction, which give us the most diverse aspect of our topic. Is is evident that this was not a laboratory experiment. Several friends, interested in psychology, the most of whom were members of Clark University, were asked to select each an object in his mental environment towards which he was conscious of an occasional change of feeling. They were asked to describe each change of feeling, to give the date, and, when possible, to give the cause of it. Eight persons responded by handing to me, some months later, detailed accounts of their experiences. There were fourteen separate records in all, some selecting more than one subject. One record covered a period of eight months; six, four months; two, two months; two, one month; while the others were general accounts or simple instances of one change of feeling. Of these, six represented topics of re-

search; two were changes in taste for food; two, family affection; one, physical exercise; one, attitude towards table board; one, the progress of a love affair; while a lady selected a piece of embroidery upon which she worked.[1] These records will require closer examination.

Table XII. gives the duration of each phase of feeling in days for the records of those who selected for their subject their topics of research. The figures in the + columns denote the days in which a liking was felt for the subject; those in the ± columns days when there was neither like nor dislike; and those in the – columns when the work was distasteful. The true sequence of these periods for each subject is shown by the vertical order of the figures. This table does not give the minor phases of these fluctuations so completely as would be desired. Positive, negative and indifferent periods are all subject to variation of intensity in the feeling, thus often making it difficult to draw fast lines between them. When, however, any unusual strength of feeling was experienced it is shown in the table by an 's' placed under the number.

From this table it is seen that frequent changes of feeling were experienced. The causes of these as given by the subjects were of two kinds. First, the state of health; and second, the encouragement or discouragement from the value of the material worked upon, or the tone of a consultation. Sickness or loss of sleep or appetite usually brought a passive or negative feeling, though this was not always the case. Cases in which the lowering of the physical tone had this effect may evidently be classed with those in which fatigue appeared in a diminished or changed activity (Experiments A, B, C, D) or distaste (Experiment E), since we may suppose that the nutritive functions were interfered with, the supply of energy thus being made less than the demand. The positive feeling which resulted from rich material or encouragement resolves itself into pleasant associations with the work, and can therefore be classed with those

[1] I cannot express too heartily my indebtedness for the expression of confidence involved in submitting some of these data. The opening of the sanctuary of the human heart for purposes of exact knowledge shows not only a confidence in the future of psychology, but also a confidence in the possibility of personal integrity.

cases in which the numerous associations and complexity of the object of attention caused it to be more attractive (Experiment E); while discouraging conditions would naturally make the subject distasteful from its association with them. When the fluctuation was not attributed to ill health or discouragement, it is my hypothesis that it was due to the exhaustion of the function exercised.

TABLE XII.

Subject.	A			B						C			D			E		
Attitude.	+	±	−	+	±	−	+	±	−	+	±	−	+	±	−	+	±	−
			1			4	(continued)			7					¼	½		
	1			1					1			2	¼					2½
			7	s	1			1		2½				1½			19	
	s																	
						3			3			2½			1	3		1
	6		5	4		s		3		22		s		1				
	s			s		1			2			2			2	3		
	23		1		2			2	s	2			8					2
		1				1	1								1		1	
			6	2				3					1		s	5		
				s	2		2									s		
	2		1	6			s	1										
						3			1									
	8			9		s		3										
	s					1	1											
					3	s		1										
				5					1									
						5		1										
					2		1											

There may be flūctuations other than those of intensity while the attitude still remains positive, as the following quotation from one record illustrates:

"There are undoubtedly fluctuations in my interest in my present work. As soon as my plans were formed in the fall I started off with elation of spirits. In perhaps a month I found myself dissatisfied with what I was doing and my interest at zero. Then came a new impulse just before the holidays, which I am glad to say is still with me.

"Within this larger curve there are smaller ones. My interest changes from one phase of my work to the other. Now I give my attention to psychology and I read with avidity

James, Ladd or Wundt. Then I find myself losing interest in this work completely, and will turn to pathology and read Clouston or Maudsley just as eagerly. Then, again, I will surfeit myself with such reading and turn to Whitaker or Foster and read neurology for several days."

Prominent among the terms describing the mental attitude are the following: 'strong revulsion,' 'revulsion,' 'disgust,' 'indisposed to work,' 'neutral,' 'indifferent,' 'decidedly more interest,' 'deep interest,' 'very high interest,' 'strong desire to be at work.'

Following are the cases of change in taste for food:

"When I was 10 or 11 I became very fond of tomatoes, stewed, and sliced with sugar, salt and pepper on. This fondness continued for 10 or a dozen years, and only diminished because it could not then be gratified. I am still fond of them, but not extravagantly any more."

"In 1892–3 I had a spell of liking candy (gum drops, in particular). It disappeared until a month ago, but is not so strong as three years ago."

I believe it is a well-known fact, although I have no specific data for it, that an over-indulgence in an article of food often causes a distaste for it afterwards. I am told that one of the popular cures for inebriety is a forced diet of food and drink always flavored with intoxicants.

The cases of family affection were both records from the same person in respect to two members of his family. The best way to give these is to copy the record. In Table XIII. x stands for one person, and y for the other. A high degree of positive feeling is denoted by additional plus signs and negative by negative signs; indifference by plus-or-minus sign. This is but a fraction of the record, but it illustrates the whole. Whenever a day came which especially reminded this person of pleasant family associations, the positive feeling was greatly increased. A letter announcing the sickness of one caused the strongest positive feeling for both members.

The record of physical exercise shows considerable variation. When not feeling well, or when other objects of interest were unusually absorbing, it was neglected, sometimes for three

or four days. Sometimes a high state of vigor caused it to be enjoyed for an unusual length of time. Although a parallel record was kept for other things, there seemed to be no constant relation between a positive or negative feeling for one and a similar feeling for another; but more extensive data would, of course, be necessary to settle this point.

TABLE XIII.

Date	*x*	*y*	Date	*x*	*y*
Dec. 29	+	—	Jan. 9	+	+++
" 30	+	+	" 10	—	++
" 31	++	+	" 11	+	+
Jan. 2	++	+	" 12	++	++
" 3	—	±	" 13	±	±
" 4	—	±	" 14	—	—
" 5	—	±	" 15	±	—
" 6	—	——	" 16	—	±
" 7	—	+	" 17	—	+
" 8	—	++	" 18	±	++

The record of attitude towards the boarding place was controlled much by the dishes served each day, but not wholly.

One describes a periodic hunger for items of news lasting for several weeks at a time, and then says:

"Resembling the above is my periodic appetite for current literature. This finds its gratification in reading magazines and short stories. It would be represented by a much larger curve than that of my news hunger. Intervals of months will elapse during which I will be indifferent to magazine stories or poetry. Then I will suddenly be possessed of the desire to get in touch with literature again."

The piece of embroidery was selected with special reference to this experiment. The design was that of a vine with leaves, and was worked in different shades of green to diminish the possible effect of a variety of colors. One long period of decreased interest lasting a month, during which the interest at times was entirely lacking, was caused by the pressure of other work. During this time but little work on the embroidery was

done. Other causes of decline of interest were a feeling of general indisposition, and the working of the stems of the leaves which was not so pleasing as the rest.

More extreme feeling would naturally appear where emotion plays a greater rôle than in the cases described last. I will quote from the case which illustrates the source of so much mental tragedy and delight—the case of love. I will change the names to avoid identification.

" *October 15*.—I believe the very essence of *A*'s character is so imprinted in me that I judge other girls by her. She is very different from Miss *B*, and I think the difference is favorable to *A*.

" *October 16, 7:15 A. M.*—I half fear the housemaid across the hall will enchant me if I cannot anchor my thoughts upon somebody that is better—though I don't know but what she is all right. I have half a mind to appeal to *A*'s sympathies directly.

" *7:45 A. M.*—Even now, in writing a business letter, I feel less dependent upon *A*, and a stronger impulse towards an absolute ideal.

" *6:30 P. M.*—The maid across the hall is not so pretty as I thought, and I am more strongly attracted to *A*.

" *October 17, 6:50 A. M.*—I had a sort of Alastor's dream last night in which I saw two girls, one of which—dressed in black and a brunette—was very beautiful, and more passive and serene than *A*. I think I can worship an abstract ideal without the aid of flesh and blood at present. Yet *A* has a beauty that I cannot expect to see equalled.

" *11:00 A. M.*—I think I could live perfectly happy if I were never again to see *A*.

" *5:00 P. M.*—*A* seems like an enthroned angel whose skirt I am not worthy to touch. I can never find anyone half so good.

" *6:00 P. M.*—When I went down stairs to-night the maid was not there. I guess she is gone. I am conscious of an impulse towards *A* in consequence, though I have a kind of tasteless exhausted feeling when thinking of her.

" *October 18, 7:45 A. M.*—How I wish I could get into

perfect sympathy with *A*. I am sure I should find a tender, gracious heart. Her stiffness comes from only a feeling of awkwardness from our separation.

"*October 18, 12 M.*—I have been thinking all the morning that I am the unworthy one rather than *A*. I did not show enough consideration for her feelings when I called last. I had too much the attitude of a critical instructor, and have not credited her with half enough of the things I wished to see in her. I see nothing whatever to blame in her. Her negative way of looking at things that interest me is simply a frank confession of lack.

"*October 19, 8:30 A. M.*—*A* has not appeared so prominently this morning. She still has that sacred, semi-divine aspect, and I see nothing in her but to admire.

"*October 21, 8:30 A. M.*—*A* holds the same place now. Last night I enjoyed quite a little feast in thinking about her.

"*October 22, 8:30 A. M.*—*A* has much the same position, though perhaps I have a bit more familiar feeling for her.

"*4:30 P. M.*—This familiar feeling—if it may so be termed —has been increasing somewhat. She no longer has that sublime enthroned aspect, but is seen as if at a nearer view. Her actual appearance, the slight blemishes of the face, and the little ways of speaking, and little movements all come out distinctly. I have a wholesome taste for her society, though I do not feel like placing her so highly as before.

"*October 23, 7:00 A. M.*—Neither like nor dislike for *A* this morning.

"*October 24, 7:00 A. M.*—More liking for *A*. Lately I have not thought of her so often as a few days ago. Now, only three or four times a day perhaps; then almost all the time.

"*October 25.*—If I do not hear from *A* pretty soon in a favorable tone I think I shall put the case of our relationship before her as candidly as I can—see if I may not expect more than a mere friendship.

"*October 26, 8 A. M.*—Yesterday afternoon I was conscious of a slight reaction. It amounted to questioning once or twice whether *A* is really well suited for me."

I am informed by the author of this record that during the

time represented by the above extract no letters or calls were exchanged between him and the object of his affection. The variations of feelings could, therefore, not have been influenced by any encouragement or discouragement given him at the time. The record continues for several months, but the above extract illustrates the whole.

There are certain well defined characteristics to this experience. In the first place it is evident that the subject had a ripe desire for the society and reciprocation of feeling of some one like his friend. This desire may be taken to represent a function which, not finding an opportunity for its complete activity, exhausts the power of mental imagining in the effort. Following in consequence of this fatigue comes:

First.—The shifting of images, as when the 'semi-divine' aspect changes to a more familiar one which develops the various personal features and characteristics. In other parts of the record is given a variety of these aspects. The usual image of the body sitting or standing in a certain position is sometimes maintained without change for several days; then the position, facial expression, or costume will be varied, thus placing her in a variety of aspects. This, no doubt, is caused in the same way that the variety in adding was brought about in Experiment B. During this time the feeling was positive; but its intensity is seen to decrease when other interests are strong, as when the business letter was written and when other persons or ideals made a strong impression. This is certainly similar to the intrusions of external interests in Experiment B.

Second.—There were the periods of inactivity when neither a positive nor a negative feeling was present, and,

Third.—Times of distinct aversion. These will be recognized as states similar to those induced in Experiment E, and no doubt represent degrees of distinct fatigue.

The relation between feeling and reason is presented in a novel way by this record. When a strong positive feeling was present, reasons for negative feeling could produce little or no effect; and also when a negative feeling was uppermost, reasons for the positive were without effect. But when a low intensity of either was felt reason had a greater influence. Often, how-

ever, feeling leads and reason tags along after, as is illustrated by the entries of October 18. While the excitation of a new interest is several times spoken of as lessening the positive feeling for '*A*,' a disappointment or the failing of some interest had the opposite effect, as is illustrated by the rise of feeling for '*A*' when the housemaid was found to be less attractive than was supposed. Different interests thus seem, temporarily at least, to work at cross purposes, each trying as if to draft off all the mental energy in its own direction. If reason is a comparison of ideas, and ideas are articulated feeling, and feeling in turn is determined by the distribution of brain energy, these relations of feeling and reason may no doubt have an explanation.

The intimate relation between thought and feeling here suggested is by no means a new idea. "Not only do feelings constitute the inferior tracts of consciousness," says Herbert Spencer,[1] "but feelings are in all cases the materials out of which, in the superior tracts of consciousness, intellect is evolved by structural combination. Everywhere feeling is the substance of which, where it is present, intellect is the form. And where intellect is not present, or but little present, mind consists of feelings that are uniform or but little formed." Mercier[2] believes that "The feelings of belief, doubt, perplexity, conviction and several others are, on their reverse side, cognitions, and may correctly be regarded either as cognitions or as feelings according as we view them on the reverse or the obverse."

In the cases of all these records we get a more or less frequent change of feeling. We should not be warranted in saying that a negative feeling always follows in consequence of exhaustion due to positive activities, or that the intensity of a negative feeling is in proportlon to the intensity of a preceding positive one, although there is some tendency for this to be true. There is more reason for believing that in general a positive feeling indicates that the function exercised is supported by a good amount of nervous energy, and a negative feeling,

[1] 'Principles of Psychology,' Vol. I., Part II., Chap. II., § 76.
[2] 'The Nervous System and the Mind,' p. 227.

the opposite condition. The influence of associations is also very marked, as if pleasing ones increased this energy and unpleasant ones detracted from it.

PART III. CONCLUSIONS.

The data here collected are naturally grouped about two points: first, the laws controlling the fatigue and recuperation of a mental function; and, second, the independence with which different mental functions operate. Experiments A, B and C have to do principally with the first; D, E and F, with the second. In G we find these two principles combined.

1. Fatigue and recuperation evidently proceed by the same laws for both mental and muscular functions, this being more apparent the more restricted the range of the mental function studied. Fatigue causes a decrease or cessation of the primary activity, thus allowing a secondary or comparatively separate one to come in and thus cause a fluctuation of the attention.[1] The more interesting the secondary idea or the stronger the disturbing sensation the less is the degree of fatigue necessary for this displacement.

2. The more complex the object of attention, the greater its æsthetic value and richness of associations, or the more it chances to meet the particular taste of the individual, the longer will it hold the attention.

3. Positive and negative feeling may result from metabolic conditions and strongly influence reason. Reason seems to be of the very stuff of which feeling is made and to represent that part of feeling which is under voluntary control.

4. From Experiment B it would seem that a mental function may be developed through the invention of economic devices and the increased power of holding mental images.

An experiment lately conducted by Mr. D. D. Hugh incidentally illustrates this last point. An oblong opening in a screen is placed horizontally before a horizontally placed cylinder, which is wound spirally by tape. When the cylin-

[1] Dr. Theodate L. Smith, who has lately been working on *the motor element in memory*, informs me that fatigue and poor physical condition have been found by her to decrease greatly the power of continued attention, giving a large mean variation in the results of her experiments.

der revolves, the subject, placed before the screen, sees a series of oblique strips of tape moving in one direction. The cylinder was then also wound by tape in the opposite direction so that in revolving, a series of oblique strips seemed to pass the first series, going in an opposite direction. The subject was required to follow one series with the eyes and to disregard the other. At first there was a frequent alternation from one series to the other in spite of the subject's efforts to keep the attention upon one. By continued effort and practice, however, the periods between the alternations gradually increased until, after a time, either series of strips could be disregarded while the attention was confined to the other.

Another illustration is furnished by recent work of Dr. E. H. Lindley.[1]

The subject, either with eyes closed or surrounded by a uniform white canopy, was required to hold in mind a simple visual image like that of a red cross on a blue background. At stated intervals this was changed for the reverse image, a blue cross on a red background. The intervals between the changes were ten seconds. At first either image could be held distinctly and constantly for only a part of this time, but after considerable practice either could be held for more than eight minutes.

In arranging the data of Experiment G it was striking what apparently slight items seemed to change the entire directions of one's thoughts and the nature of one's mood. A few sympathetic words, a chance idea, the incidental discovery of a new point in the policy of a person or institution, or even an imagined personal attribute was enough to determine one's mood for days or weeks. The question suggests itself whether such influences and even much slighter ones may not be brought under judicious control for the advantage of the mental and moral victims of our physical and social conditions.

Part IV. Theoretical.

It may be that a somewhat strained effort appears in the endeavor to reduce all mental functions to the same formulas here arrived at; yet it seems safe to postulate on the basis of the foregoing data, and what is known of cerebral localization, that the differences in the objects of our attention correspond to differences in the nature and location of the required brain activity, and that emotional colorings result largely from this and the intensity of the activity present.

The idea of cerebral localization for the different senses and

[1] Through the courtesy of the above named gentlemen, I am allowed to refer to their work while it is still unpublished.

for different ideational processes is by no means new. The centre for sight has been located in the angular gyrus about the posterior end of the parallel sulcus and in the occipital lobe. Ferrier has localized the centre for hearing in the first temporo-sphenoidal convolution. Bilateral lesions of the first and second temporo-sphenoidal convolutions in man cause complete deafness. Anatomical considerations and direct experimentation place the olfactory centre in the anterior extremity of the temporo-sphenoidal lobe. The sense of taste is thought to have its centre closely related to that of smell, and is believed by Ferrier to be near the lower extremities of the temporo-sphenoidal lobes. Certainly the inability to outline exactly the areas for the various sensory and motor centres does not show that these centres are not definitely organized, but that they are diffused, as might be expected, rather than confined exclusively to any one locality. Professor Flechsig[1] has found a number of association centres not immediately connected with the sensory and motor areas. Two-thirds of the human cerebrum, he says, is taken up by these. The region they represent is made up by the frontal lobe, a great part of the temporal and posterior lobes, and extends deeper into the brain to include the island of Reil. These parts seem to have to do only with internal adjustments, and may be called the 'association or coagitation centres.' "It is particularly the disease of the association centres," he continues,[2] "that causes insanity; they are the special objects of psychiatry. We find them changed in those mental diseases the nature of which is made clear to us because the microscope can distinctly discover the cause for change, cell for cell and fibre for fibre; and so we can show directly what result it has for the mental life when they are either too much or too many of them disorganized, or both."[3] According to Ferrier, "There are centres for special forms of sensation and ideation, and centres for special motor activities and acquisitions, in response to, and in association with, the activity of sensory centres; and these in their respective cohesions, actions,

[1] 'Gehirn und Seele,' by Dr. Paul Flechsig.

[2] *Loc. cit.*, p. 24.

[3] In a note the author admits this to be theoretical.

and interactions, form the substrata of mental operations in all their aspects and in all their range."[1] I will also quote from Dr. Hyslop, who says:

"If we accept the doctrines of the more recent English school—that individual sensations or ideas exist only as members of a connected, conscious series, and that consciousness, therefore, can never be conceived as a mere sum or mere product; and if we believe with Hume that consciousness is a mere succession of ideas without inner bond or connection, or that it is the series of our actual sensations (John Stuart Mill)—it may be thought possible that there are individual nervous elements which possess isolated and distinct forms of consciousness."[2]

In the light of this support from both psychologists and neurologists it cannot be called radically theoretical to regard experiments E and F as supporting the idea of cerebral localization of the higher functions. This is demonstrated in a practical way whenever we vary our pursuits to avoid their monotony, seek recreation, or take up a new fad. In ordinary life our attention is constantly being diverted by disturbances and the necessity of attending to routine duties. Sometimes these intermissions are sufficient altogether to prevent pauses resulting from fatigue; and when they do occur we simply say we are tired of writing, or reading, or staying at home, and very wisely take diversion as a matter of course. Such diversion, it would seem, serves to allow the exhausted function to recuperate, so that one's normal pursuits may be safely taken up at a later time.

The neurological basis for the fact that a complicated object holds the attention longer than a simple one may be that there are distinct nerve elements which are exercised by each of the qualities an object possesses, and that while some of these elements give us the consciousness of one part of the object, those corresponding to another part are resting, and so preparing to take up their work when the first elements become fatigued. In this way the more complicated the object, the less would there

[1] 'The Functions of the Brain,' p. 147.
[2] 'Mental Physiology,' p. 113.

be required of the individuals in this division of labor.[1] This hypothesis requires that the mind does not hold all of a complicated object in consciousness at once. A little reflection only is required to convince one that all objects of attention, however simple, are really made up of different qualities that are easily distinguished. By holding the attention upon an object having but a few of these, he is readily impressed with the extreme shortness of the time that each can appear continuously. Let the reader concentrate his attention upon an imaginary just visible grain of dust suspended in a permanent position two feet before his eyes, and with simply the qualities of color, and position relative to himself. At first, by the effort to visualize, it is perfectly distinct, but it is only for an instant; then it either disappears or takes on qualities of motion, colors, or some other imagined elements. "There is no such thing as voluntary attention sustained for more than a few seconds at a time," says Professor James.[2] In working upon reaction times Professor Cattell tried delaying the signal preceding the stimulus for the reaction, thus keeping the subject in a state of strained attention. It was found in this way that the time of the reaction lengthened after one second.[3] What the time would have been if the object of attention had been reduced to its barest possible dimensions can only be inferred. But any one who tries the experiment with the grain of dust, just described, will be convinced that it would be very short. It would be of great value to know whether all of these qualities in perceiving an object pass through the mind singly or are fused. If they pass singly —and I am inclined to this opinion—they pass so quickly as to give the impression of being fused. I believe it is an error, however, to say we can divide the attention between two objects at the same time, although this is a popular theory among psychologists. An experiment supposed to prove this is described by Wundt.[4] By means of a falling slide, several letters of the

[1] In the work of Dr. Lindley, already referred to, it was found that, while a very simple object could be visualized for but a short time, a complex object could be retained indefinitely.

[2] *Psychology*, Vol. I., p. 420.

[3] *Mind*, Vol. XI., p. 240.

[4] *Physiologische Psychologie*, Vol. II., p. 291.

alphabet are presented to the area of clearest vision for about 0.08 of a sec. After this short exposure the subject is able to name four to six of the letters. This, accordingly, is supposed to show that the attention can be divided between four to six separate ideas at the same instant.

I have tried a similar experiment by showing to the subject small colored discs arranged upon a screen behind a revolving shutter, which allowed an exposure similar in length to that of Wundt's experiments, and required the subject to give the number of discs seen. I obtained a result similar to his, but observed a period of hesitation between the exposures of the disc and the verdict of the subject. This led to the question as to whether the perception of these different objects was really simultaneous or consecutive. That is, was not the mental after-image retained long enough and with sufficient freshness to allow the attention to pass quickly from one to the other and so perform a process of rudimentary counting? This after-image is a sort of mental photograph of the objects, which fades after a moment, and not like the more elaborate mental reconstruction which Wundt distinguishes as a later and longer process. If this is the case, the number of separate objects remembered simply gives the number of consecutive objects towards which the attention can be directed during the short time before this impression fades.

For the purpose of getting another method of deciding whether the attention can be divided I arranged upon a horizontally revolving kymograph drum a belt of paper which carried on it two series of upright lines arranged in the following way: (*d*, *e*, Fig. 10.)

FIG. 10.

a and *b* represent openings of the same size in a screen placed vertically before the drum so that the series of lines *d*

would pass behind opening *a*, and series *e*, behind *b; c* is a fixation point for the centre of vision. The experiment consisted of two parts:

1st. With the eyes fixated upon *c* and with one of the openings closed, the fastest rate of turning for the drum was found at which the single series could be counted correctly, there being twenty-nine lines in each series, but the subject not knowing the number, the rate being gradually decreased until the correct number could be given with certainty.

2d. With the eyes fixated as before and with both *a* and *b* open, the subject was told to divide his attention between the openings. The fastest rate was then found at which the subject could count the lines in both series at once.

If the attention could really be divided, then it should take but little if any longer for the double series to be counted than for the single. As the attempt to keep separate counts for each series was very confusing, a single count was kept for both. Following is given the number of seconds for the first and second parts of the experiment for each subject.

TABLE XIV.

Subject.	Part 1.	Part 2.
Sd.	3.4	8.9
Hn.	6.6	18.5
Ly.	9.0	26.0
Sh.	12.1	28.0
Hh.	10.4	23.9

This table shows that for all of the subjects it took more than twice as long to count the double series as to count the single. By dividing the time for the first series by 29 we get the time necessary for the attention to change from one line to the other, plus the time necessary for the line to be perceived. For Hn. this was about 0.23 sec., and for Sh. and Hh. a little less than twice this. If we multiply this by the number most commonly given for the objects between which the attention can be divided, 5, we get a little over 1 sec. (1.15) for Hn. and a little over 2

sec. (2.10) for Sh. for the time necessary in Wundt's experiment for the subject to get the number of objects by successive acts of the attention, or the duration of the visual impression. In Experiment A the fastest rate for reading letters was practically the same.

This experiment seems to show that for all practical purposes, at least, the attention cannot be divided. It seems evident that the attention points in only one direction at a time, and then points to but one object, and perhaps to but one perception element of that object at a time. We have to suppose that in cases of animated active thinking the same principle holds in the succession of single images and perception elements that was found to be present in the succession of more complete ideas in Experiment B. There, it will be remembered, the necessary degree of fatigue for a change of attention was lessened by a high state of interest in a secondary direction. In the more microscopical side of the process, a high state of tension in the image centres due to nutritive processes would correspond to the conscious interest on the conscious side. The degree of fatigue necessary for one image to succeed another would thus be made less and the succession made quicker. Fatigue is evidently a prime factor in securing the *succession* element in thinking.

May it not be convenient to establish a unit of mental work along these lines? A single image, however simple, may be too complicated for the basis of such a unit, but the perception element, being the seeming atom of the mental process, would be more suitable. Such a unit might be *the amount of mental work necessary to maintain a perception element in ascendency before the mind one-hundredth of a second*, as such an element could probably not be retained continuously for nearly a second. The amount of effort necessary for this would doubtless vary, but the amount of work would perhaps be constant.

Since in all states of consciousness we must be conscious of something, it is safe to affirm that *direction* is a constant quality of consciousness, and present in all states of attention. I will take the liberty of christening this as one of the *dimensions* of consciousness. There are two other qualities that are also pres-

ent in all states of consciousness. These are *time* and *intensity*. These two and *direction* I regard as constituting the three *dimensions* of consciousness, or those qualities always necessary to its existence. These deal, of course, with extensive features rather than intensive, looking at it from the outside rather than from the inside. The theories of James and Wundt regard it sufficiently from the standpoint of *direction*, but not enough from that of the other qualities.

I have already dwelt to a considerable extent upon *direction* and *time;* the former distinguishing the object or idea uppermost in the mind at any given instant, and the latter the duration in time units of such ascendency. *Intensity* has here been touched upon only incidentally. It is that which distinguishes a strong feeling from a weak one. In Experiment A it was that which distinguished 'strong revulsion' from 'indisposed to work,' and 'deep interest' from 'indifferent.' In Experiment B it appeared in the power of unusual rapidity in adding; and in the last case of Experiment G, in the beatific aspect of '*A*.' This is expressed more psychologically, perhaps, in the '*Interesse*' of Stumpf, but 'intensity' may be applied also to neural conditions.

These *dimensions* may be combined in a variety of proportions to produce the great variety of mental states well known to all. "The tone of feelings," says Dr. Hyslop, "may be taken as dependent upon the intensity and quality of sensations, *plus* associated ideas." In excitement the intensity is high and time short. In 'vacant' moods the intensity is at a low ebb and the time lengthened. The nature of the mental content with the various feelings, so far as they result from mere associations, is determined by the direction. Momentary changes of the direction to comparatively irrelevant objects—the value of which may be to tell whether they are irrelevant or not—in which the time and intensity are both reduced, seem to make up the 'fringe' of consciousness.

How, then, shall we define attention, and what is its relation to consciousness as a whole? Consciousness more properly is the generic term, while attention is particular. One comprehends a large range of special phases, while the other refers to

a single phase composed of the direction, time, and intensity belonging to it, the same as all the kinds of horses we know make up our general idea of a horse, while a certain horse is only one of that large class and has a certain degree of each of the horse qualities. *Attention, then, is a single phase or section of consciousness.* One phase, however, is as much attention as another. It is not one state as opposed to another, but one state as distinct from another. I may be inattentive so far as my inkstand is concerned, but attention exists the same, since my mind is turned to some other object. The process of 'apperception' is going on just the same. The power of holding the mind in a certain general direction is without question of great value, but those who cannot do it should not be deprived of intellect, they simply need training to control this particular dimension. But what shall be said of the adjustment of sense organs in regard to attention? This leads us to a still more theoretical part of the results, the probable neurological basis of the phenomena just studied.

What sort of picture of the brain do these results justify? If we look at a black disc upon a white background, as soon as those parts of the retina stimulated by the white surface begin to tire, rays of light will seem to be emitted from the disc. Soon the white surface around the disc will appear to be illuminated much above the rest. This seems to show that that part of the retina covered by the black color has not been exhausted so much as the surrounding parts, and that a certain amount of energy is allowed to filter out in some form to the more exhausted areas about. Since the retinas, morphologically speaking, are parts of the brain, this suggests that one brain region can assist a more exhausted neighboring region and that neural energy, whether in the form of lymph charged with nutritive elements, or in some more elaborated form, tends to distribute itself equally throughout contiguous tissue. In the brain we have the gray matter composed of an extremely fine interlacement of nerve-cell processes, not only of the nerve cells which lie in that particular gray matter, but also of those in other parts of the nerve centres. The dendritic processes which largely compose this have chiefly a nutritive func-

tion, although Ramón y Cajal[1] believes that they may be also conductors of nervous currents between neighboring cells and others at a distance. The chief function of the body of the nerve-cell is also that of nutrition. Nansen[2] believes it has no other function than that of effecting the nutrition of the whole cell and especially of the axis-cylinder process. Schäfer says that while the nutritive function may be the only essential one of the nucleated body, yet there are many cases in which it serves for the transmission of nerve-impulses.

In vision it seems probable that the alternate appearance and disappearance of indistinct objects is brought about by the relation between the supply of energy to the cells innervated by the optic stimulus and the demand for it necessary for continuous vision. This energy is used faster than it is supplied, and there follows in consequence a period of decreased activity due to a degree of exhaustion. The nutritive process, however, continues, and the area stimulated becomes again active through this accession. The exhaustion is again repeated, and so on. The fatigue and recovery of the nerve cells controlling muscular activity would seem to be accomplished in the same way. When, however, the demand for energy is increased the result seems to be different in the two cases. In vision, temperature sensations and probably in hearing, it will be remembered that the stronger the stimulation the more constant was the activity of the sense organ, while in muscular contraction the greater the weight lifted the quicker was the fatigue and the larger the proportion of inactivity. In Experiment E it was found that when the object of attention was complicated or had a special æsthetic value it held the attention longer, while in Experiments A, B and C the fatigue was in direct proportion to the amount of work. Since a lengthening of the time of any special mental activity must in all cases require a proportional increase in the amount of energy consumed, it seems probable that different conditions of nutrition or innervation were to some degree present in the cases of sense stimulation and Experiment E on one side, and muscular contraction

[1] 'Croonian Lecture,' Roy. Soc., March 8, 1894.

[2] 'Historical Elements of the Central Nervous System,' Bergen, 1887.

and Experiments B and C on the other. In one case the increase of demand increased the supply of energy, while in the other it seemed to have no such effect.

I will not attempt a complete explanation of this, but give what to me appears to be the principal cause. In the muscular contraction the demand for energy was greater than the supply; hence, the enforced pause, or decrease in the amount of work done. If the demand had been much less to start with, a gradual increase of it would have been met with a corresponding increase in the supply until the maximum rate in the supply had been reached. With the sense stimulations a maximum state of anabolism was necessary in the nerve cells to make the slightest stimulations become conscious. As the stimulations became stronger, a lower state of anabolism was sufficient to make it conscious, or, in other words, the available supply of energy for the sensation became increased, and more rapidly even than the increase in the stimulus. Our experiment with the black disc shows also that the surrounding areas in the retina assisted in this, and that their assistance was more marked in proportion to the degree of fatigue in the stimulated area. This transmission of energy may be accounted for in one of three ways: By the circulation of nutritive lymph from one area to the other, by the passage of nutritive solution between contiguous tissue by the process of infiltration, or by the transmission of a more elaborated form of nerve energy similar to a nerve impulse or identical with it.

The same reasons for the fatigue effect in muscular contraction would doubtless explain the same phenomenon in Experiments A, B and C, since here the demand for energy was extreme and the variety of function closely restricted. In the case of Experiment E, where æsthetic or associative values greatly increased the amount of energy spent in some one general direction, an explanation must be sought for the supply of so unusual an amount of energy.

In the brain the lymph spaces and the communications between them allow much freedom in the passage of nutritive material from one part to another. There are also reasons for believing local hyperæmia to take place where cortical ac-

tivity makes special nutritive support necessary. A gradual functional increase in this kind of support due to exercise might explain the increased power of an established function, but would not account for a large amount of support already available, nor for the formation of new relations. Since we have found reason for supposing that each object of attention innervates a more or less restricted locality in the cortex, any object with which associations have been formed might be represented diagrammatically by a centre from which radiate in various directions association fibres relating it with other centres and giving the object its qualities and its position in our conscious experience. Until such relations are established we may regard, according to Spencer and Mercier, the consciousness which such centres excite as feeling rather than cognition.[1] To produce feeling in the various degrees of intensity with which it appears in psychic life, nothing is more evident than that it is evolved at the expense of great nervous energy, and yet it is possible for this to appear with very slight rational articulation to explain its presence. We may see objects or hear tunes that excite a storm of emotion, but which convey little or no suggestion as to the explanation of their effect. In presenting this in the diagrammatic scheme just proposed, we may suppose the radiating association paths to have degenerated so as to be unconscious, but that they still represent lines of nervous energy which concentrate at the supposed centre. This would seem to account for the vague feeling of appreciation accompanied by prolonged attention in Experiment E. Conversely, is it not probable that a demand for nervous force, which is caused by the frequent and persistent retention of one or more mental images, will form new paths of conscious association along the tributary lines of transmitted force thus necessitated? This would imply a tendency on the part of nerve force to diffuse itself through nerve tissue in the direction of localities of low intensity, and this supposition is supported by our knowledge of neurology and our observations of fatigue in the retinas. Nerve cells which reach a high anabolic condition

[1] Herbert Spencer's 'Principles of Psychology,' Vol. I., Part II., Chapter II. Mercier's 'The Nervous System and the Mind,' Chapter IX.

give slight discharges as a result simply of this condition and the general disturbance which the nervous system is continually subjected to, without any specific stimulus being applied to them. As distinct discharges these are largely unconscious, but result chiefly in raising the mental tone. It is naturally the strongest discharge, however, which tends to become conscious, and, if this were in the vicinity of an excited area, there would be a tendency for it to run into it and form a conscious association, especially since cells in the vicinity of such an area would be likely to be discharged by the diffusion of impulses from it.

In connection with this it may be asked whether the familiar phenomenon of association by similarity may not have an explanation along this line. Similarly sounding words or similarly appearing objects might naturally correspond to centres having locations near each other in the brain. Hence, the stimulation in one centre resulting from the presentation of one such word or object would bring the similar word or object into consciousness through the radiation of nervous disturbance from the first centre to its neighboring one. The confusion between like sounding words so often noticed in children might be explained by this, and by the lack of fixed paths of association which become more firmly established with increased maturity.

It is well known that as a cortical region comes to have a distinct function, its nerve processes become more developed and the axis-cylinders become medullated. We also know that as an object of attention comes to figure more and more in consciousness, its qualities come to be recognized and its relations more definite. Its simple *thingness* disappears and gives place to qualities that are regarded as belonging to it and which come up with it from association. This is certainly evidence that definite neural relations have been established. Feeling thus seems to organize itself into cognition and distinct thought as neurons take on specific functions by means of extension and medullation. From the fact that nerve-elements do not proliferate after birth the development of brain organization can not depend upon this. "On the other hand," says Dr. Hyslop, "it is probable that, in those regions which are most exercised,

mental activity involves a greater development of the protoplasmic apparatus, and of the system of collateral nervous paths."[1]

The selective power of inhibition is evidently the greatest factor in bringing about this organization. The irrelevant ideas are by this means suppressed and the more promising ones allowed to establish firm and lasting relations. It is, doubtless, this kind of development which allows the philosopher or crank to see everything in the light of his pet theory, and which gives to each of us our characteristic habits of thought. It is the lack of hard continuous thinking, says Hirth, which makes the mind so subject to the disorganization found in the cases of distraction in insanity. The lack of this discipline keeps our mental possessions in the state of a mosaic instead of making them into a continuous harmonious unit.[2]

This tendency of continued mental effort to cause relations to be formed between different parts of the cortex, and perhaps between very widely different parts, is a factor opposed to what we may regard as the mere natural grouping of related ideational centres by themselves. This grouping—which would evidently depend more upon the permeability of the paths of intercommunication than on close spatial relations in the cortex—must have been the cause of the isolation of the centres for different mental functions found in Experiments E and F. This natural grouping would seem to result from the qualities and associations which objects most readily present to us, while the more laboriously formed paths correspond to logical relations. In Fig. 11 this is expressed diagrammatically. The association path between those centres corresponding to the perception elements of the same object are more numerous than those between different general objects of attention that are less frequently associated (as *h*, *i* in Fig. 11). The paths relating the general groups of ideas *e* and *m* are less direct and less numerous than those between *i* and *e* because they are less frequently united by experience.

When many such paths representing logical relations have been formed we may suppose that energy in one part of the brain is more easily brought to the support of an exhausted centre than before. "When," says Mercier, "an entirely new

[1] 'Mental Physiology,' p. 54.

[2] G. Hirth, 'Lokalisation Psychologie.'

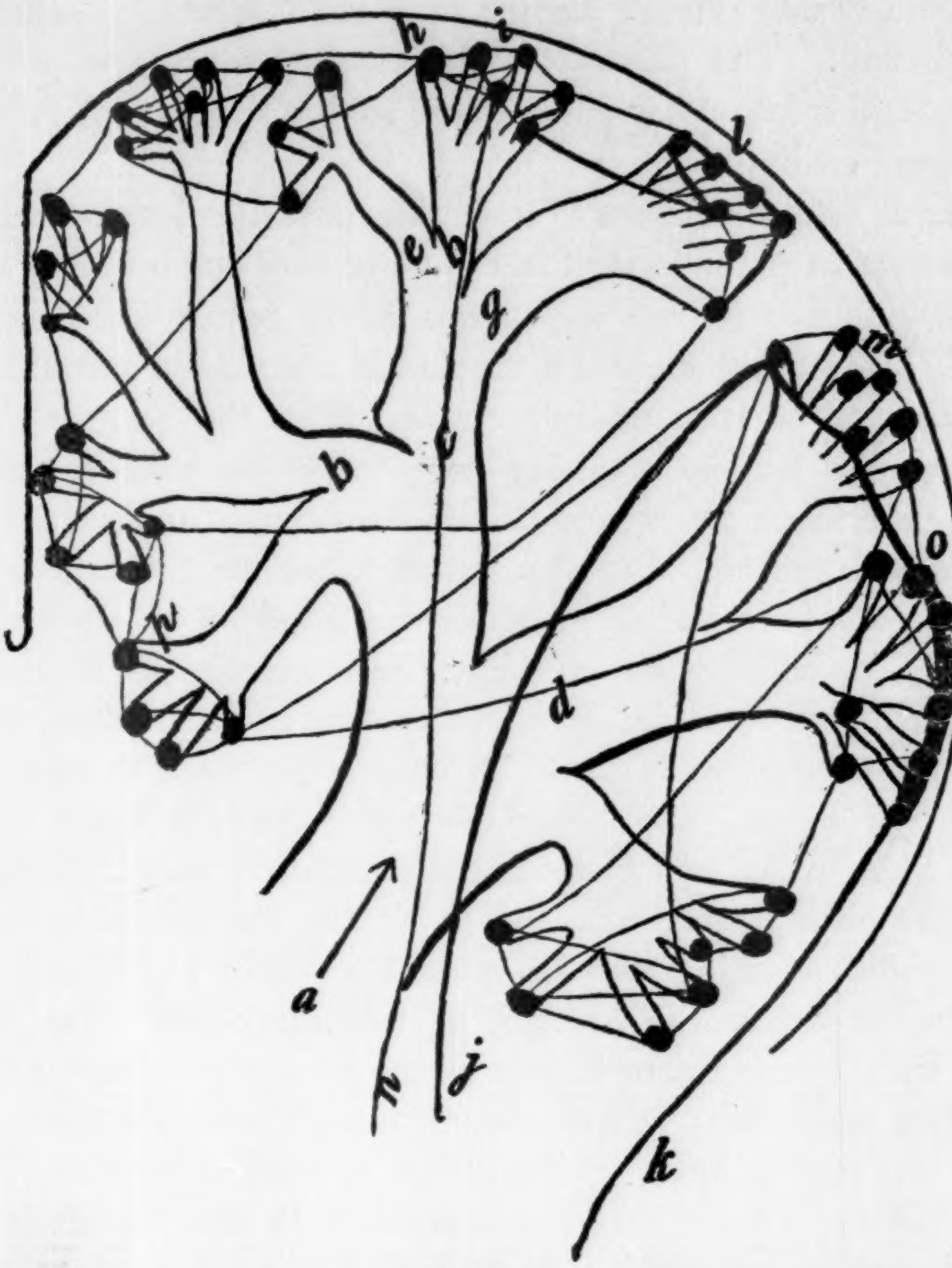


FIG. 11.

Let the accompanying diagram represent a portion of one side of the cortex. The large trunk beginning at *a* represents the channel of nutrition for the parts above; *b*, *c*, *d* represent the branches of this trunk that lead to areas representing larger groups of ideas, like home, occupation, amusements, etc.; *e*, *f* and *g* represent the divisions of such a general group, corresponding to the various instruments of occupation, etc., and the round dots like *h*, *i* the seat of conscious mental activity and the areas that correspond to the simplest perceptive elements of objects. The finer lines that connect these represent association fibres; *j* is the sensory tract and *k* the motor tract for a reflex movement. The association paths connecting the centres involved in this circuit are represented as being so enlarged as nearly to obliterate the existence of different cen as separate steps in the process.

relation is established in the mind—when we have an entirely novel thought—then there is the passage of a current through

a previously untraversed portion of ground-substance—through a virgin soil. The passage of this current rearranges some of the molecules into polar parallelism, so that subsequent currents pass more easily."[1]

Let us take a moment to trace the possible development of an association path, formed in the more easy and ordinary way. A sensation is received which has never before been experienced. As such it creates a tension in the cortex through the liberation of nervous energy coming from the ganglion cells affected, but has no meaning for the person until related to other experience by means of the confluence of this nervous tension with others. Let us suppose, however, that it does find an idea present in the form of similar tensions in other nerve cells. Now whether we consider these tensions to be caused by electro-motive force, by some system of hydraulics, or by molecular vibrations, it would be natural for them to spread in conductive tissue, and hence to travel towards each other. When this union has been accomplished, a new association path has been opened up, and in future the sensation which was without meaning will be related to other experience. It will, in the future, be brought in whenever the ideas associated with it reoccur, or it may be the means of bringing them in. The more this chain of associations is used the more certain is one part to bring up the others connected with it. The conscious experience which corresponds to this process is the line of association, every step of which is at first consciously taken, but when repeated becomes passed over more and more quickly, until finally the whole line appears as but one association. It is in this way that general ideas are formed. My idea of a horse, for instance, is made up of a multitude of once conscious associations, but which now are forgotten. They are all present, however, though unconsciously so, in the fusion which gives the general idea.

There are, of course, all degrees of fusion according to the frequency or number of past associative acts for any particular line. The process has not gone far when we recognize, as we so often can, the slow accumulation of energy from various

[1] *Loc. cit.*, p. 370.

ideational centres as the force of many reasons for some motor accomplishment. It is the energy combined in this way which gives the dynamic force or impetus to acts of volition. Automatic acts may result from a single idea, but the voluntary act appears usually as the conclusion to a syllogism whose premises are at least two antecedent connected ideas.

It is to the association which has become unconscious that we must attribute sense organ adjustment and its relation to attention. No doubt, at first the turning of the eyes, poising of the head, and even the adjustment of accommodation and adaptation were once conscious, and made with special effort to put the sense organs in accord with a mental image. We have only, however, to suppose the paths of association between the visual image and the organ of vision to become enlarged by use, when the related motor mechanism would cause adjustment by the mere tension of liberated energy in the visual centres. In the experimental work of Dr. Heinrich, already referred to, it was found that visual images caused a disturbance of the pupil of the eye, while other images did not. Evidently the movements of adaptation are so immediately under the control of the visual centres that the power of voluntary adjustment has been lost.

It may be well to draw in more general terms the outlines of the picture which nutritive processes in the brain present. For convenience of presentation we may suppose the cortex to be divided into general areas which roughly correspond to general directions of attention. Thus, the mental images and associations which I have in regard to my home may have their origin in one such area, while those in regard to my occupation are largely confined to another; and so on, each general class of ideas depending upon its own particular location. Relations may, of course, be formed between different areas, but since we may suppose the internal relations between different parts of such an area to be more numerous than their relations with the parts of any other area we have a general basis of division. We will suppose these larger areas to be made up of smaller ones which correspond to the details of the general objects of attention, as the rooms and furnishings of my home, or the different books

used in my occupation. Furthermore, we will suppose each single object, such as room and book, to be make up of various features, the final elements of perception, each of which has its corresponding area within this area. The source of nutrition for each of these smallest areas we will suppose to be from the general fund of the next larger which contains it, and so on, the same as each twig of a tree depends upon the branch, and the branch upon the trunk; but that cross supportive relations, as from twig to twig, are also present, though more difficult and of less degree. These last would correspond to association fibres. (See Fig. 11.)

Each of the largest areas would have the only means for the outlet of its energy through the activity of the smallest that compose it. Wherever the tension of escaping energy would be greatest, there, for the moment, would be the seat of consciousness. The content of consciousness, whether my pen or a page number, would be determined by the locality of the activity; and the order of these localities in their turn of discharge would be controlled partly by the association fibres, which, as they become larger and larger by use, would be an increasing factor in this control, and partly by the degree of anabolism in the various cortical centres. Without this influence of association fibres each cell would have a regular rhythm of anabolism and discharge, varied only by the nutritive supply.

Bevan Lewis says, "the cell is subject to a constant supply of nutritive plasma, it gradually assumes a state of nutritive instability, and will necessarily discharge its accumulated energy in accordance with the simple law of nutritive rhythm, the resulting stable equilibrium is succeeded by a measurable period ere the potential energizing of the cell has once more brought it up to its former state of instability. Were this all that occurs the process of storage and liberation of energy would be a simpler rhythmic process than the more compound rhythm which actually pertains to mental operations."[1]

Granting a rhythmic tendency to the cell as influencing mental activity, it is certainly natural, from a purely physiological

[1] Bevan Lewis, 'Mental Diseases,' p. 110.

point of view, to expect closely related groups of cells to have rhythms for the same reasons, and this is precisely what seems to have been observed in all the experiments described. While the author just quoted believes the nucleus to be the chief factor in regulating the cell discharge, it seems to me that Mercier[1] is more correct in regarding this to be due to the influence of cell fibres. These, we may suppose, conduct enough additional energy to the already anabolized centre to make the intensity of its discharge greater than that of any other in the cortex for the moment, and thus have a controlling influence in determining the mental content.

We certainly also have mental phenomena which indicate similar relations to exist between the larger areas. A sufficiently strong impulse coming through association paths may augment the energy of a fatigued or dormant area sufficiently to cause action, when otherwise it would be impossible. By this means remote motives may come to control conduct, or one's life may be raised above the control of merely temporary impulses. A well-known writer has said that good acting and good morals are synonymous. Let a 'dirty foreigner' brush against a lady's dress on the street and she is filled with disgust, but let the feeling of pity be brought into her sensory motor arc, as by the offender's falling into a faint, and the motor accompaniments of a very different attitude are adopted. In Experiment G it will be remembered that a strong positive feeling for relatives was induced by the news of sickness. It is a frequent situation in fiction for a young lady's attractiveness to be greatly enhanced when found to be possessed of wealth. A sufficient inducement will make the worst of bores tolerable.

This may be expressed in Fig. 11 by supposing the circuit *n*, *i*, *l*, *p* to discharge through *k*, when the circuit is usually confined to *j*, *m*, *o*, *k*.

We need not suppose, however, that there is only one line of neural associations at once. The more or less automatic processes, the snatches of rhythm, the humming of the popular tune, now and then break into the more conscious lines of mental activity, even without the aid of sense disturbance, to bear tes-

[1] 'Nervous System and the Mind,' p. 73.

timony to their existence. What we get in consciousness is primarily a succession of highest intensities, whether they are connected by associations or not. In Experiment B it will be remembered that the fatigue of the adding functions was often shown by the appearance of thoughts which were not even suggested by the work. Yet there usually appears a certain unity and method in the progress of thought which suggests the subordination of many centres to the one line of associations discharging. As an illustration may be cited the inhibitive effect of a strong sensation, or an unusually clear perceptive state, as in surprise. Movements, especially of an automatic nature, cease; the sense organs become adjusted in accord with the sensory idea, and all unrelated activity, mental as well as physical, seems paralyzed. It may be that there is some immediate reduction of intensity in other cortical centres in favor of the one excited that causes this state of inequality, besides the direct increase in the excited centre from the stimulation. If this is so, the chances for an equal intensity existing in different centres at the same time would be greatly decreased. There are, however, times when this condition does seem to exist, as when many distracting inclinations cause momentary confusion, or when indecision comes from the balancing of reasons for and against some line of conduct. The ass starving between two bundles of hay is not a frequent spectacle, however, and it may be that natural selection has provided us with some neutral arrangement to avoid this.

The theory of Ramón y Cajal is in accord with this. He believes that when a sensation or idea excites a certain region of the cortex, the perivascular neuroglia cells cause hyperæmia in that locality of nutritive lymph, thus supplying energy (evidently at the expense of surrounding areas) for the increased intensity of mental action.[1]

The work of Roy and Sherrington leads them to conclude that "the chemical products of cerebral metabolism contained in the lymph which bathes the walls of the arterioles of the brain can cause variations of the calibre of the cerebral vessels; that in this reaction the brain possesses an intrinsic mechanism

[1] See His u. Braune, Archiv für Anat., 1895, p. 377.

by which its vascular supply can be varied locally in correspondence with local variations of functional activity."[1]

This activity may, however, be stimulated to an unhygienic degree. Over-exertion of the brain may lead to acute mania, melancholia, dementia, *folie circulaire*, and general paralysis.[2] Even without marked intellectual or moral weakness, even in brilliant mental accomplishments, says Professor Flechsig,[3] many persons show brain weakness in the nature or inequality of their behavior. Dr. Tissié[4] finds that with sane and robust persons extreme physical fatigue, as that caused by a long march or bicycle trip, or any regular prolonged rhythmic muscular work, excites distinct temporary psychoses which have the same outer manifestations as the pathological psychoses of morbid subjects. Among these are loss of volition, pholias, hallucinations, amnesia, hypermnesia, automatisms, and a well manifested state of suggestibility. These same psychoses appear in the insane, only more readily than in the healthy person.

Morbid subjects of this kind, and those living in extreme old age, in whom the psychic life centres about old and deep-seated associations, seem to be victims of chronic fatigue. Nerve cells found in these subjects stain more deeply than the unstimulated cell.[5] If stimulation is continued in healthy subjects for a long time the protoplasm becomes deformed and crenated. Finally a state of complete collapse is reached in which the nucleus and protoplasm lose all power of taking on stains. Dr. Tuke gives us the following phases as they result from over-exertion:

First there is excited an increased blood supply, "the consequent dilation of the vessels is maintained by the lessened alkalinity of the cerebro-spinal fluid, and the discharge of energy of the cells becomes irregular in consequence of the presence of more blood than is needed for repair, and the discharge takes

[1] *Journal of Physiology*, Vol. XI.

[2] See J. Batty Tuke, 'The Insanity of Over-exertion of the Brain.'

[3] *Op. cit.*, p. 32.

[4] Ph. Tissié, "La fatigue chez les débiles nervoux ou 'fatigues'," *Revue Scientifique*, November 21, 1896.

[5] See Dr. C. F. Hodge, 'Changes in Ganglion Cells from Birth to Senile Death,' *Journal of Phys.*, XVII., Nos. 1 and 2. J. Batty Tuke, *op. cit.*, p. 22.

place at a lower level of cell nutrition and function." As a result we get in order active hyperæmia, passive hyperæmia and congestion; leucocytes are deposited, indicating a state of inflammation; red corpuscles in various stages of decay and large masses of pigment are deposited, and proliferation of fixed connective-tissue cells and exudation occur.

In optical phenomena we have positive or negative after-images according as to whether those parts of the retinas concerned have been stimulated only enough to start an activity which continues to liberate energy, or have been stimulated to exhaustion. So in mental activity we have, on the one hand, vigorous action and positive feeling in response to a suggestion, thus indicating a high anabolic condition; while, on the other hand, we have negative feeling and either delayed or irrelevant activity, indicating a low catabolic condition. Reveries, day-dreams, involuntary thought in general, and especially dreams while sleeping, take on these after-image characteristics. Mr. Julius Nelson[1] states that in his youth he was subject to dreams in which were repeated certain frightful scenes. He found, however, that these could be prevented. I will give his own words.

"My mother taught me a remedy for bad dreams which I applied with immediate and universal success, viz., on composing myself for sleep, the object of a dreaded dream was, by voluntary act, brought before my mind, and while held there I said mentally, 'Shall I dream of that?' (here visualizing the scene which past dreams had taught me to fear) and then the subject was dismissed with a confidence that I should not be troubled by that dream for that night. Should the feared scene again intrude before sleep came, it must once more be dismissed by the formula or my work was in vain. Thus, one by one, I rehearsed the list of bugbears every night, making special effort not to treat pleasant subjects in that way, for then I knew they would not be dreamed about."

I have myself successfully followed the same principle of exhausting certain ideational centres to prevent them from troubling me in sleep; mental activity irrelevant to the centres

[1] *American Journal of Psychology*, May, 1888.

exhausted by this exercise evidently following from this principle of negative mental after-images.

As illustrated by Experiments A, B, C, etc., the first effect of fatigue is inequality in the amount and quality of work. Experiments E and G showed how when this exhaustion is balanced, or when an effort is made to balance it by special exertion, a negative feeling is induced in connection with the object of attention. When this exertion passes the bounds of safety the milder forms of insanity spoken of by Dr. Tuke and Professor Flechsig seem to come as the result. What I wish to call especial attention to is the negative feeling. This is also excited in regard to objects which have harmed us or caused pain. Fear is a typical form. Experiment G has doubtless served to show how broadly negative feelings figure in the lives of all of us. With some it becomes chronic, as when in the 'blues' or melancholia it indicates a general low state of vital energy. It is probably due to irradiations of this feeling which give to things which in themselves have no emotional tone a 'tinge of sadness,' such as the moanings of the ocean and the sighings of the pines.

In consideration of the relation of negative feeling to fatigue and resulting insanity, we seem justified in regarding it as a natural means for self-preservation. Evidently it comes as a warning, which, if disregarded, is prevented from acting as it is intended to in keeping us from insanity, or at least from a state of exhaustion which would delay the ordinary rate of recuperation, or lay us liable to disease. When it appears as fear or dislike for a person or situation, we instinctively recognize its value and profit by its signal. When it appears as a sign of over-exertion, evidently it should no less be heeded. This suggests that there is yet to be preached a gospel of scientific recreation.

On the other hand, a positive feeling seems to indicate a high anabolic condition. While the failing of vital force is indicated, as in the aged, by a decrease of physical activity and disconnection of thoughts, one general direction of attention changing to another without the usual steps of association, a surplus of energy is evidenced by vigorous mental action and a healthy

exercise of the imagination. It is this state which makes the waters laugh, the breezes play, and which gives the optimist his sanguine hopes. Now the objects of attention bloom out with attractions never before seen, and cold logic cannot say they are lacking. Now is seen 'Helen's beauty in a brow of Egypt,' and the strongest impulses to beautify and to self-expression appear as bubblings over of this energy. "Deep and tenacious cases of spontaneous attention," says Ribot, "have all the characteristics of unassuaged passion which unceasingly recommences in the effort to satisfy itself."[1] With a strong and menacing negative feeling in one direction, which may emphasize a still stronger positive feeling in another, is it any wonder that many persons often overstep the bounds of propriety and find themselves branded as aliens? And does this reflect more upon the personal morals of such than upon customs which insufficiently recognize the needs of our common nature?

There is also a large class of sensitively conscientious people who afflict themselves with reproaches or torturing self-examinations, because the emotional strength which once gave them a constancy of feeling has been diminished by ill health, made unconscious through more perfect cerebral organization, or else exhausted by over-exertion. Such should be taught the basic principles which underlie our mental constitution; and that mental hygiene is as imperative as physical hygiene, the same general principles applying to both.[2]

[1] Psychologie de l' Attention,' p. 17.

[2] Perhaps the most severe criticism to be placed upon the present treatment is that there is the proportion of two of theory to one of fact; the ratio more properly being inverted. If, however, the experiments described help to indicate a fruitful region of experimentation, and one in advance of the classical reaction-time experiments, their end will largely have been realized. But even with such limited data one is impressed with the common conviction that facts are greater than theories. Any theory, therefore, advanced in the present state of psychology can hardly be expected to serve more than as a suggestion for a more complete one.

TABLE XVI.

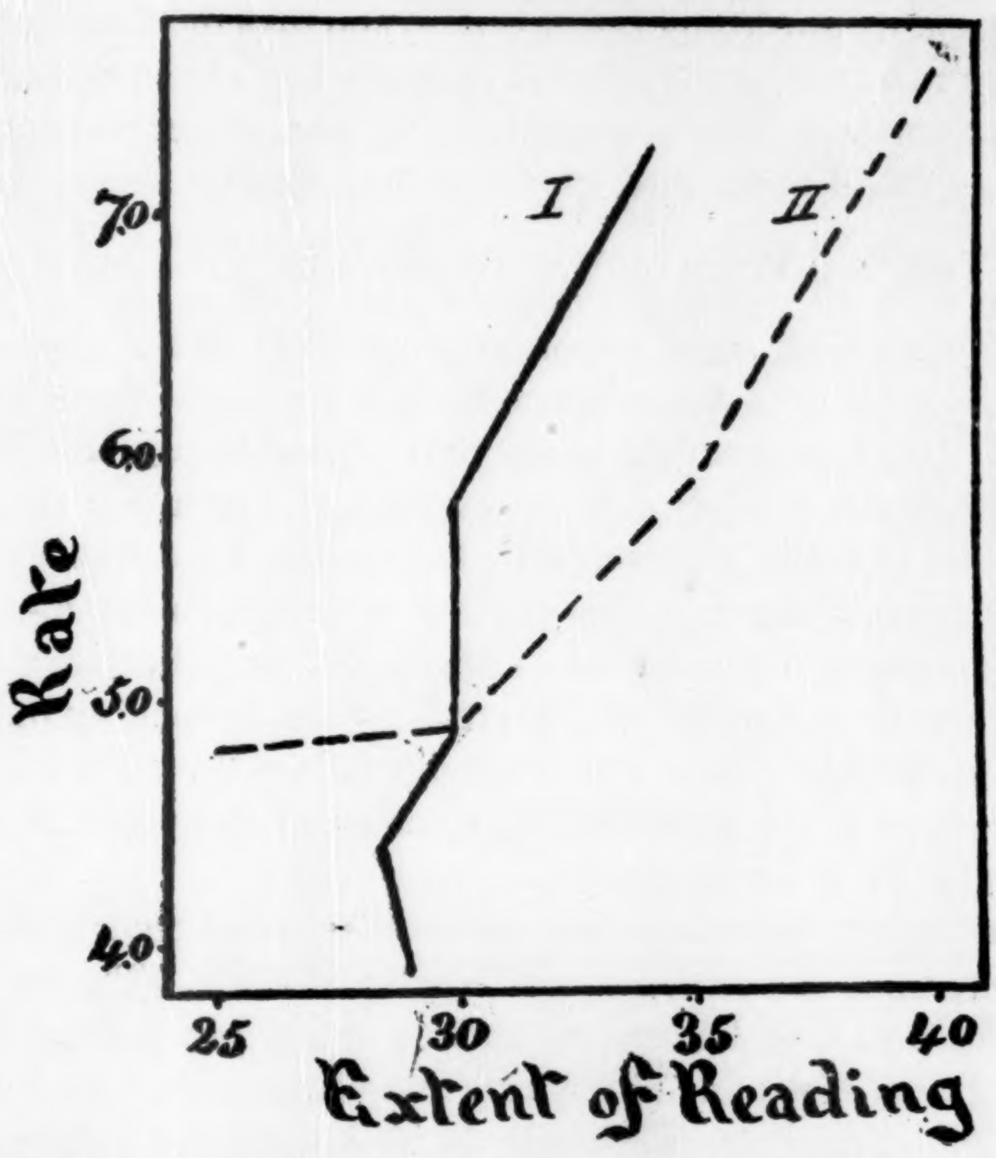
EXTENT OF READING DETERMINED BY READING RATE (I.).

Class	XX	X	M	A	AA
Rate	3.9	4.4	4.9	5.8	7.3
Extent	29.0	28.5	30.0	30.0	34.1

RATE BY EXTENT (II.).

Extent	25	30	35	40
Rate	4.8	4.9	5.9	7.6

Curve 16.



Practice always plays a large part in the earlier stages of operations which involve a combination of muscular and mental activity; copying, for example, or shorthand writing. But one can reach a point beyond which the effect of practice is indefinitely small. This, however, is usually because the *physiological* limit of quickness has been reached; and if reading were to any great extent a physiological process we might well suppose

all college students to have passed the point at which practice ceases to have an appreciable effect. But these considerations apply only to operations in which we have made conscious and continued efforts to reach the highest skill. Reading, however, is only slightly physiological, except, of course, in so far as all mental operations are conditioned on the activity of brain cells. So it comes about that practice continues to show a marked effect even in those subjects whose extent of reading is very large. Word-recognition is more and more fully handed over to the centres governing reflex action, and thus the time required for the process of recognition is decreased. The reflex arc is shorter than the higher conscious circuit, and, moreover, nervous impulses travel faster through fibres than through cells.

§ VI. The Relation of Eye to Voice in Reading Aloud.

A question of some importance remains: When one reads aloud how far does the eye ordinarily travel in advance of the voice? This is a practical query with regard both to *intelligent* and *intelligible* reading. If the eye is only two words ahead of the voice, in reading new matter, the reader is not likely either to understand the thought—without returning upon it—or to make a listener understand it. Moreover, with the large number of words in English which are identical in spelling but different in pronunciation and meaning, unless the sight and the understanding are somewhat in advance of the voice, mispronunciations will be frequent.

An attempt was made to ascertain the factors contributing to this difference of position between eye and voice. The number of words perceived but not yet spoken at any given point in the reading was determined by a very simple method. At definite points in the reading, previously decided upon but unknown to the reader, a card was quickly slipped over the page, and the number of words spoken after the view was thus cut off was recorded. Of *objective* influences might be mentioned the legibility of the words (depending upon spacing, 'leading,' size of type, color of paper, etc.), the length of the lines, the position in the line at which the interruption took place, and the effect of punctuation. These factors were little studied, as our

interest was mainly in the mental and not the external conditions.[1] An octavo volume was used (length of line 3⅝ inches), the matter being of ordinary difficulty and containing no technical words. In the first trial the subject did not know the purpose of the experiment, and it was quite unexpected by him when the page was cut off from his view. Of course he could be surprised in this way but once. Succeeding trials, however, under the same objective conditions and with only the subjective difference that he knew how he was to be treated, gave results not appreciably different. Much depends upon the position in the line at which the view is intercepted. When the reader is pronouncing a word at the beginning of a line, the eye is on an average 7.4 words in advance of the voice; in the middle, 5.1 words; and at the end, 3.8, giving an average of 5.4 words. Thus the space between eye and voice is very elastic, expanding and contracting with each line, but with a uniform regularity,—except indeed where special conditions are introduced; an unfamiliar word, for instance, would decrease the distance to zero, or a familiar phrase might increase it to a dozen words. The fact that a new or strange word calls a halt to the eye's advance illustrates the well-known principle that we cognize familiar words as a whole, and do not 'see' each letter separately; misprints usually pass unnoticed except by the proof-reader.

The distance between the words which the voice is uttering and the point of regard being so variable for different parts of the line, the number of words by which the eye precedes when we commence the utterance of a sentence is not comparable with an average of the beginning, middle and end of the line, but rather with a test made by intercepting the vision at a corresponding point in the line. The comparative numbers thus obtained were 5.4 and 5.1; that is, after the long pause, which a period allows, the eye lengthens its lead of the voice.

Of *subjective* influences determining the distance between eye and voice obviously one is the familiarity of the reader with the thought and language. Rate of reading is also closely re-

[1] Legibility has been carefully studied by Sanford: *Relative Legibility of the Small Letters, Amer. Jour. Psych.*, I., p. 402.

lated, especially in two of its factors, eye-mindedness and quickness of visual perception. The correlation is given below:

TABLE XVII.

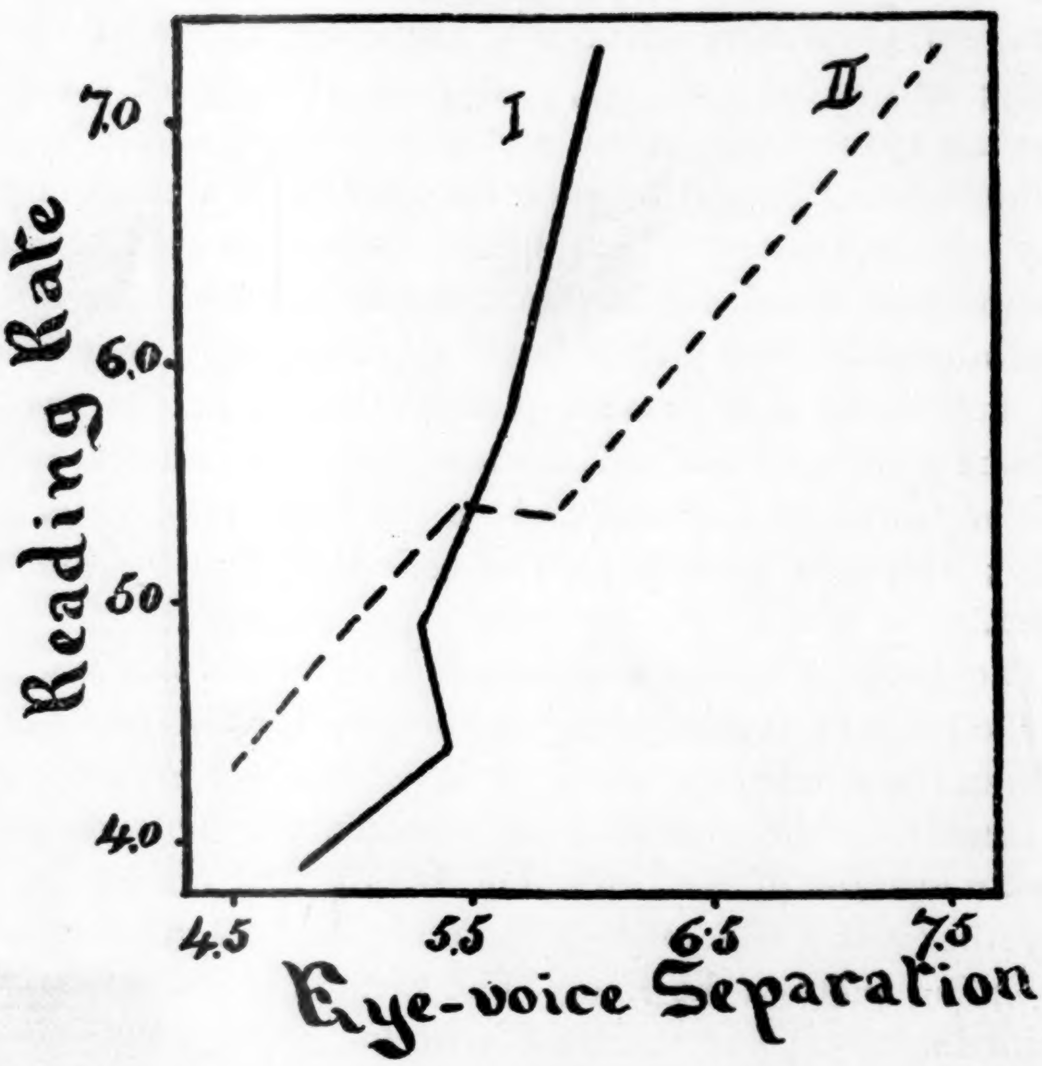
EYE-VOICE SEPARATION DETERMINED BY READING RATE (I.).

Class	XX	X	M	A	AA
Rate	3.9	4.4	4.9	5.8	7.3
Eye voice	4.8	5.4	5.3	5.6	6.0

RATE BY EYE-VOICE SEPARATION (II.).

Eye-voice	4.5	5.0	5.4	5.8	7.5
Rate	4.32	4.96	5.41	5.33	7.24

Curve 17.



If, as is thus shown by the table and Curve 17, those who are rapid silent readers read farthest ahead of the voice in reading aloud, and if a certain considerable distance between eye and voice is a condition of intelligent and intelligible reading, it follows that here again, as in silent reading, rapidity is an advantage.

It is perhaps worth considering whether we mean, when we say the eye is any given number of words in advance of the voice, that the understanding also is, or whether it occupies a place intermediate between eye and voice. Does comprehension keep pace with visual perception, or does it lag behind? There is also another consideration, namely, that visual perception itself has not advanced so far as the tests seem to indicate. As in the experiments with the exposure apparatus, retinal images may be formed at the very moment when the view is intercepted. Some time is required (as physiology tells us) for the conveyance of this impression to the brain; further time is spent (psycho-physics adds) in the conversion of the impression into a sensation; and still an additional interval (psychology shows), though this is perhaps inappreciable, before the sensation becomes a perception. These physiological and psychical processes may take place after the physical stimulus has been removed. But aside from this, and after we have reached *word-perception*, does the understanding of the *meaning* of the groups of words advance along with this? The question must probably be answered in the negative, though the number of experiments made were too few to justify definite conclusions. The method of testing consisted in giving the subjects such sentences to read as "A large bass was caught in the river," "Does in the park are not so fleet as when running wild," "When the child saw the tear in her sister's dress she was very sorry," each containing a word which would probably be mispronounced unless its true meaning in the sentence was understood before the word was spoken. This misapprehension would probably take place unless the understanding of the words was in advance of their utterance by two or three words.

§ VII. Résumé.

1. Colors are more easily perceived than geometrical forms, isolated words than colors, and words in construction than disconnected words.

2. The visual type of persons are slightly more rapid readers than the auditory type.

3. Rapid readers not only do their work in less time, but do

superior work. They retain more of the substance of what is read or heard than do slow readers.

4. Lip-movement is a serious hindrance to speed of reading, and consequently to intelligence of reading. The disadvantage extends also to reading aloud.

5. Apart from external conditions, such as time of day, physical fatigue, etc., some of the influences contributing to rapidity of reading are largely physiological, as visual perception; others are of mental endowment, as alertness of mind; or of training, such as concentration of mind; still others are matters of mental equipment rather than intellectual ability; for instance, extent of reading and scholarly attainment. The order of importance of these is probably as follows: visual perception; practice, as determined by amount of reading from childhood onward; power of concentration; mental alertness, estimated by rapidity of original composition; scholarly ability, as decided by college records.

Some of these factors are doubtless not ultimate; differences in quickness of mental operation, for example, have, in all probability, corresponding differences in the functional activity of brain cells.

It might be added as a particular verification of these general conclusions that by far the most rapid reader of all those tested is a young woman whose extent of reading is exceptionally broad, and who possesses a strong tendency toward eye-mindedness, a marked power of mental concentration, and intellectual ability of a high order—all of which have been found to be positive factors contributing to rapidity of reading. She is a brilliant conversationist as well, and in writing cannot make her pen keep pace with her thoughts, thus showing an unusual quickness of mind.

Appendix.—Personal Sheet.

1. Do you consider yourself a very slow, slow, medium, rapid or very rapid reader?

2. Do you enjoy and profit by having some one read aloud to you?

3. Do you read aloud to yourself? Does this aid you in comprehending and retaining?

4. Do you habitually move your lips or tend to do so when you read? And if not habitually, do you ever do so? Under what circumstances?

5. What processes accompany your reading? In particular, do you imagine the sounds of the words read? Do you imagine yourself speaking the words? Is the whole process a purely visual one of reading the words, and nothing more? Answer as fully as possible.

6. Do you recall quotations readily? Do you recall and commit verse readily? Would your regard your memory for what you have read as very poor, poor, medium, good, or very good? Answer for different kinds of reading if possible.

7. Are you readily disturbed when reading by talking or other noise going on in the room?

8. Do you comprehend and retain better the substance of a lecture, or the same matter read by you once only, in the form of an article? Estimate the extent of the difference.

9. Would you regard the amount of your reading as very limited, limited, medium, extended or very extended? In what lines has your reading been most extensive?

10. Do you write very slowly, slowly, medium, rapidly or very rapidly? Answer, first, regarding mere mechanical writing, as from dictation or copy; secondly, regarding composition, as in writing a letter or an essay.

11. Add any special information bearing upon the questions above, that pertains to your reading and other habits.